ON TO NEPTUNE

ASTRONOMY

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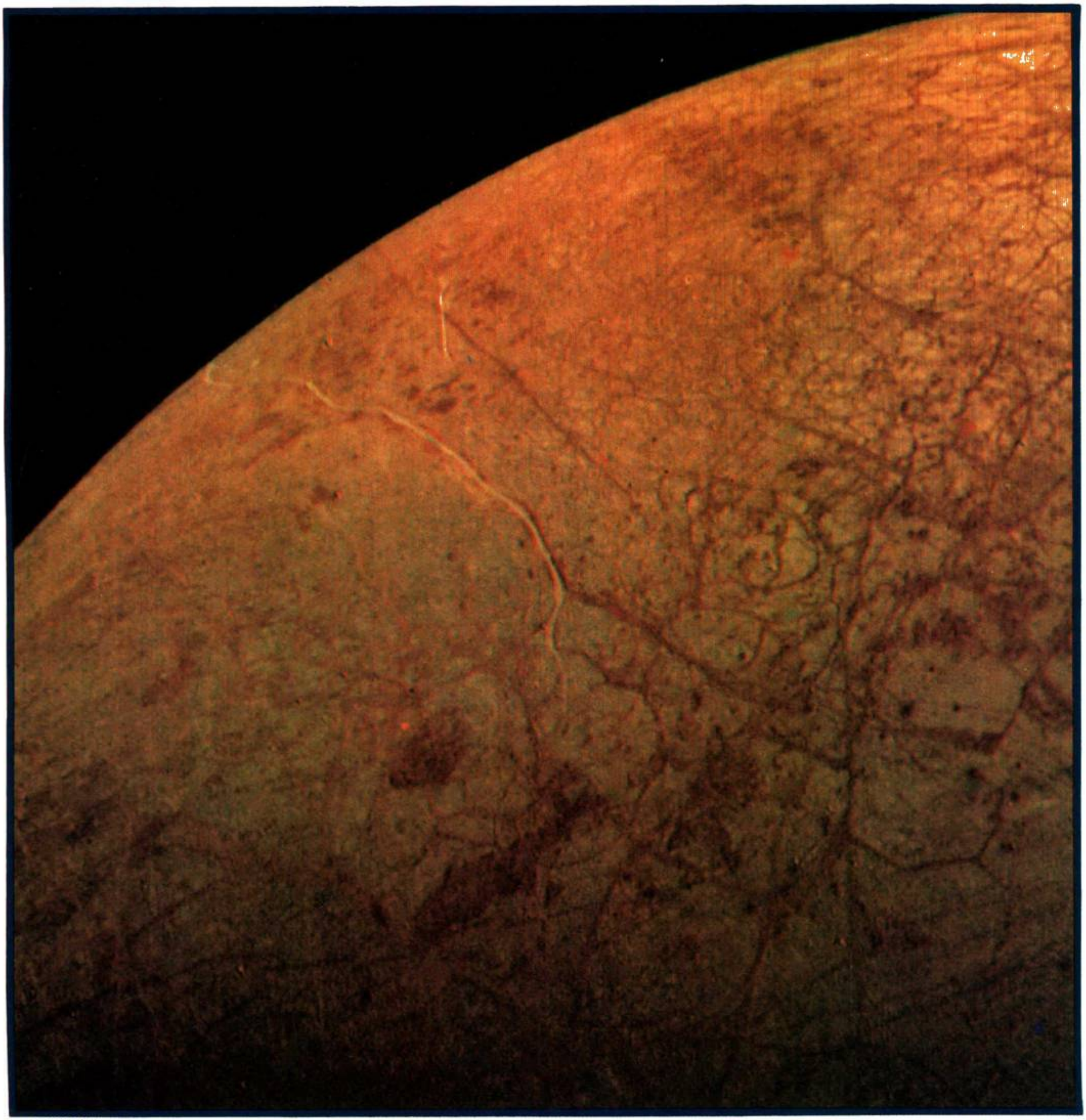

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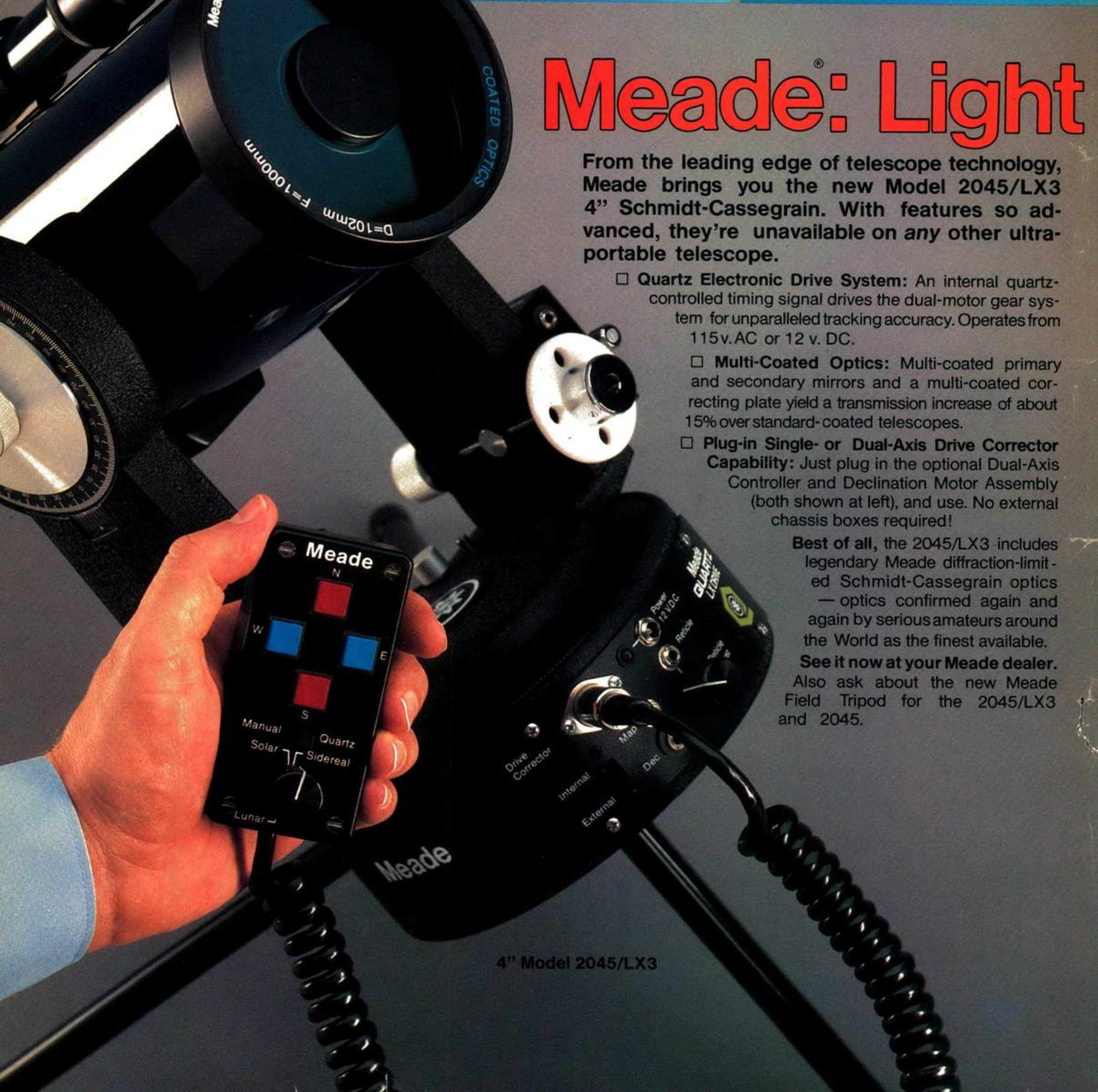
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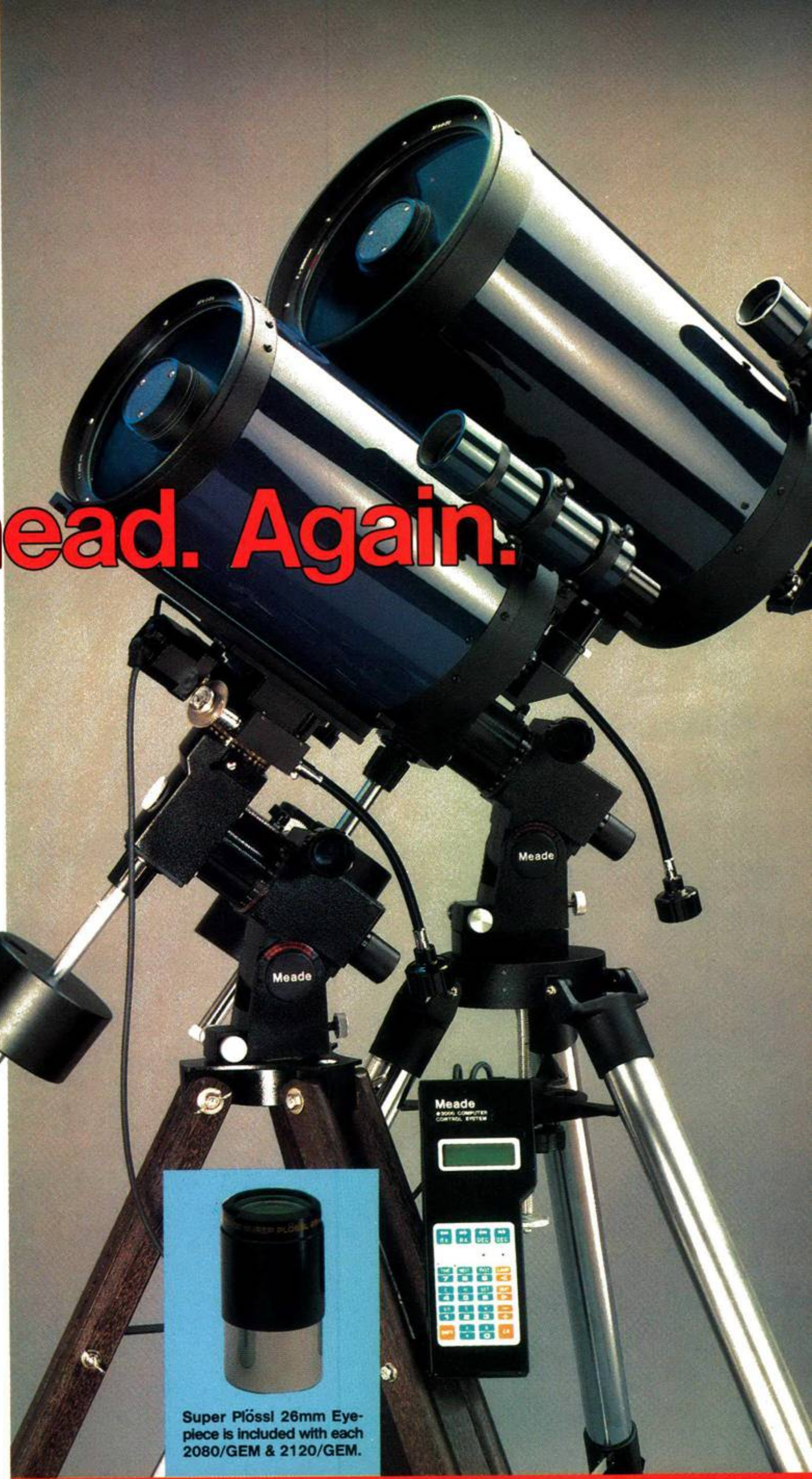

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Cover: Europa may be the smallest of Jupiter's Galilean satellites, but it is by no means the dullest. This month's Stellar Frontiers shows you what the view would be like from this icy world. NASA/JPL image. These pages: A different moon stars in this picture of a total solar eclipse. Annemarie Franklin and Wendy Carlos photographed the July 31, 1981, eclipse from Siberia with a 180° fisheye lens.

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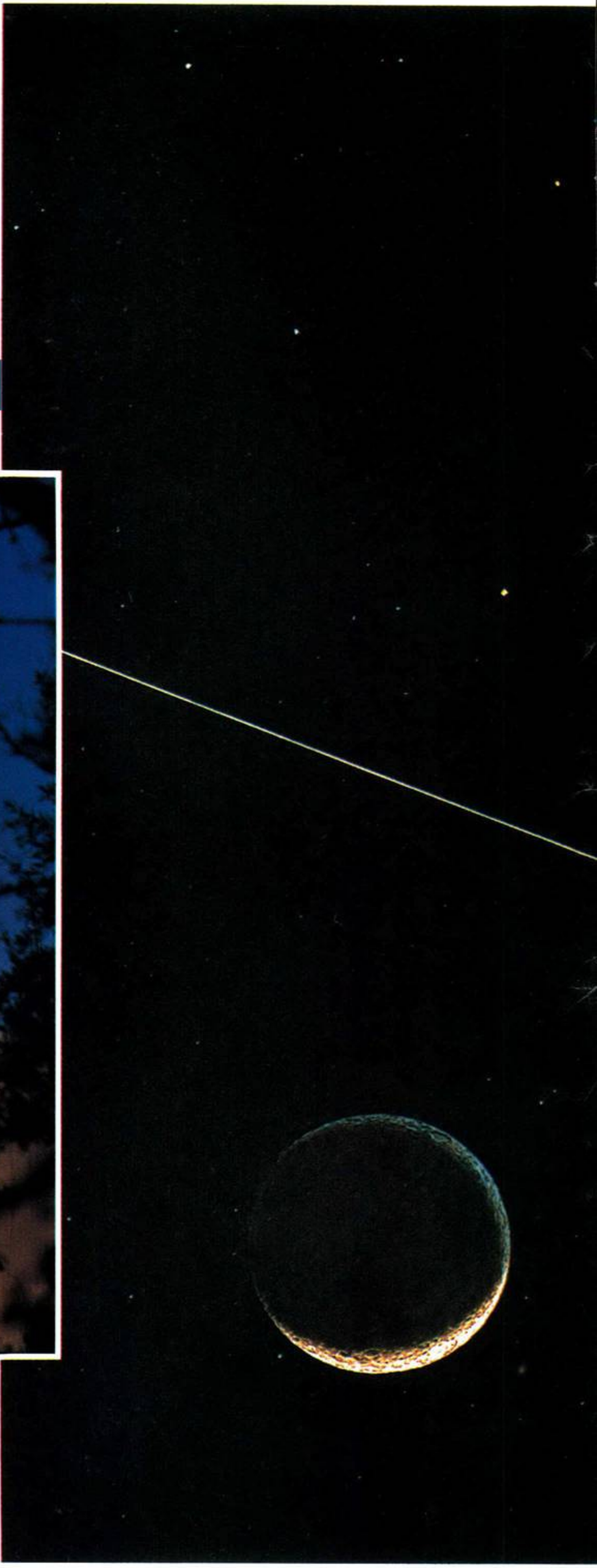
On Course for Neptune

by Charles E. Kohlhase



Above: The launch of Voyager 2 on August 20, 1977. NASA photo.

Right: After diving over the north pole and being deflected downward, Voyager 2 must be content to view narrowly lit crescents on the southern limbs of remote Neptune and Triton. A computer graphic precision "template" was used by space artist Don Davis to create this view looking back at Neptune seven hours after closest approach. NASA/JPL illustration.

DONALD E D
7-7-81

The history-making Voyager 2 spacecraft, launched nine years ago, is a robot without peer. As if its plethora of Jupiter and Saturn discoveries were not enough, it completed the third leg of its "Grand Tour" by exposing the remote vista of tilted Uranus, much to the delight of its loyal human supporters.

Having unveiled the mysteries of Uranus, Voyager 2 is now on course for an encounter with Neptune in late August 1989. Planetary scientists expect the probe to reveal a great deal about the planet's two known satellites (especially Triton), the quizzical ring-arc system, the atmosphere and weather of the planet, and the presence of a magnetic field and trapped particles.

If the findings at Uranus are any indication, Voyager's observations at Neptune should be equally fascinating.

Uranus proved anything but dull. Jet streams, twice as fast as those on Earth, move in unexpected directions for an atmosphere that receives more heat input near its poles than at its equator. Its strong magnetic field, generated deep in the planet's interior, wobbles like a top from its 60-degree offset to the planet's rotational axis. Trapped subatomic particles, akin to Earth's Van Allen radiation belts, bombard moon and ring surfaces, darkening methane ices over periods much shorter than the age of the solar system.

Above the cloud tops on the sunlit side of the atmosphere, a vast extended region of hydrogen atoms and molecules emits ultraviolet energy. But the intensity of these emissions is too strong to be explained by sunlight power alone. This new emission, termed "electroglow," has scientists searching for another source to power the energetic electrons that apparently interact with the planet's extended hydrogen corona to produce these intense emissions.

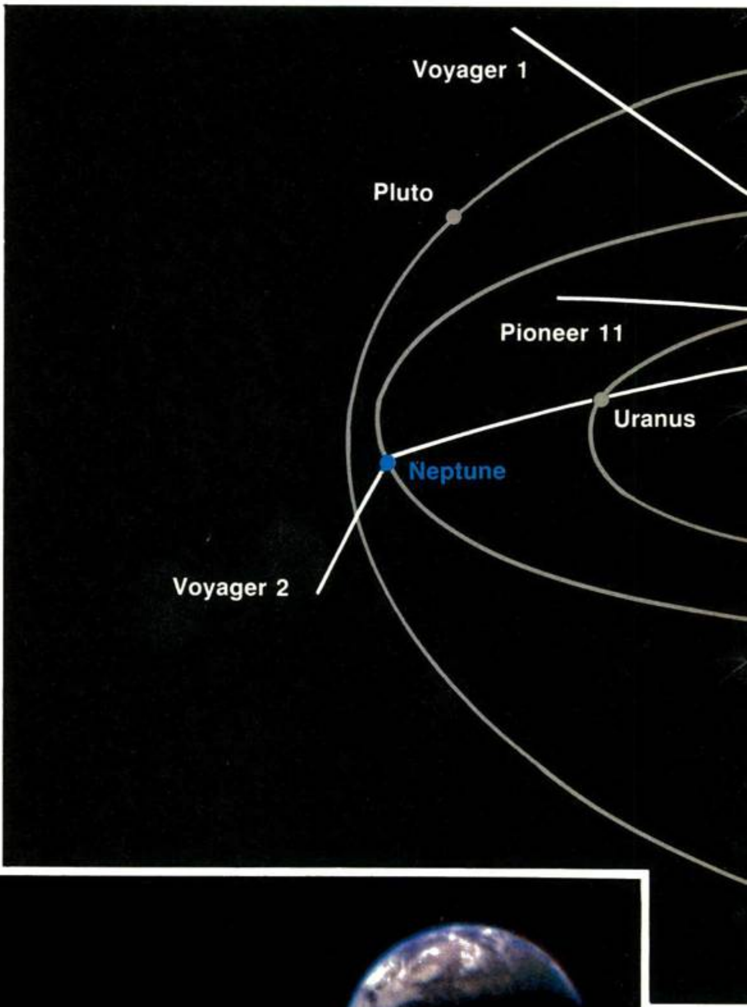
Ten newly-discovered moons ranging in size from 40 to 170 kilometers in diameter orbit between Uranus and the path of Miranda. On a smaller scale, black chair-size boulders comprise much of the rings, as finer material spirals slowly toward the planet, the victim of drag from the extended hydrogen corona.

Undoubtedly, the *piece de resistance* was Miranda. If ever a magnificent engineering feat was rewarded with an equally spectacular scientific discovery, the "Miranda mosaic" was just such an endeavor. Imagine, having to estimate the precise location of a small world three billion kilometers away that you plan to streak past only once at a relative speed twenty times faster than a rifle bullet, while panning your camera to follow the target with a pointing accuracy better than one-tenth of a degree!

The reward was a set of remarkable pictures of a small satellite that would prove to be one of the most interesting bodies in the solar system. Not the heavily cratered orb of shiny, super-hard ice scientists expected, Miranda's mottled surface revealed almost every type of terrain found so far in the solar system. Voyager geologist Laurence Soderblom suggested that Miranda might be the result of a body that had accreted from smaller bodies, had its heavier rocky material sink to the core, experienced a later breakup, and finally reformed into a jumbled mixture of ice and rock.

On to Neptune

Despite Neptune's rank as the solar system's fourth largest planet, it is too faint to be discerned by the unaided eye. Even in large telescopes, it appears as a tiny bluish green dot. Similar to Uranus in size and color, the two



planets differ in many respects.

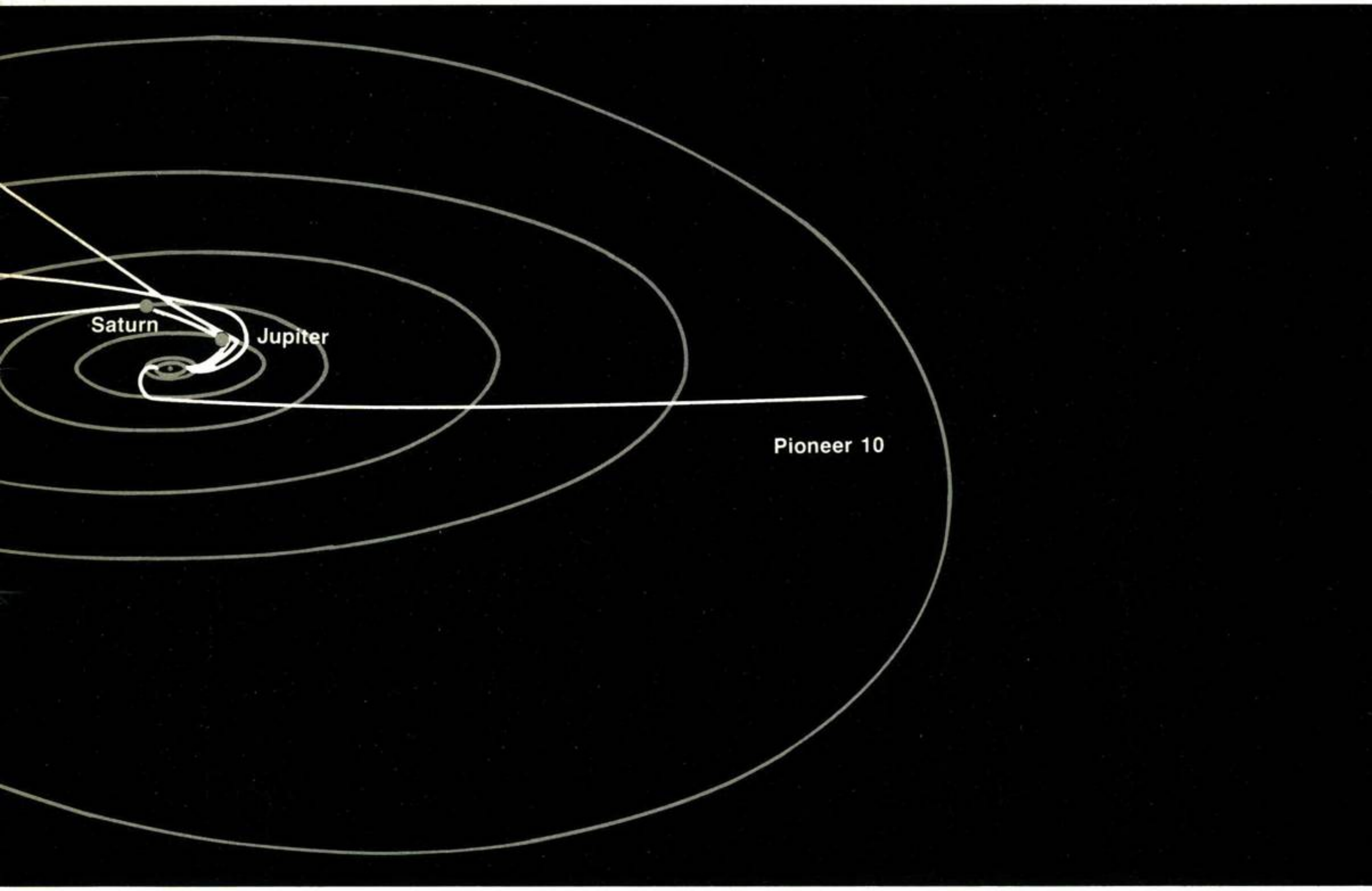
Neptune is slightly smaller in diameter but is more massive, equal to 17 Earth masses as opposed to 14 Earth masses for Uranus. Uranus is tipped on its side, but Neptune's spin axis has a modest tilt of 29 degrees. And although Uranus has lost much of the heat stored during its formation (a fact recently verified by Voyager 2), Neptune is still warm but cooling.

Infrared observations have shown that Neptune's weather varies over hours, days, and years, with old features fading and new ones continually appearing. Broad atmospheric features have been photographed moving across the planet. By tracking these features astronomers estimate the rotation rate of the outer atmosphere to be about 18 hours. The rotation rate of the inner core has yet to be determined.

The two known moons of Neptune were discovered over a period of 103 years. William Lassell discovered Triton — a huge satellite — in 1846, less than three weeks after Neptune's discovery. Gerard Kuiper found tiny Nereid in 1949. Harold Reitsema and colleagues inferred a third possible moon when an unseen object blocked a star's light for eight seconds on May 24, 1981. Since that time, however, several stellar occultations have indicated that a thin or fragmented ring, rather than a third moon, was probably the culprit in the Reitsema observation.

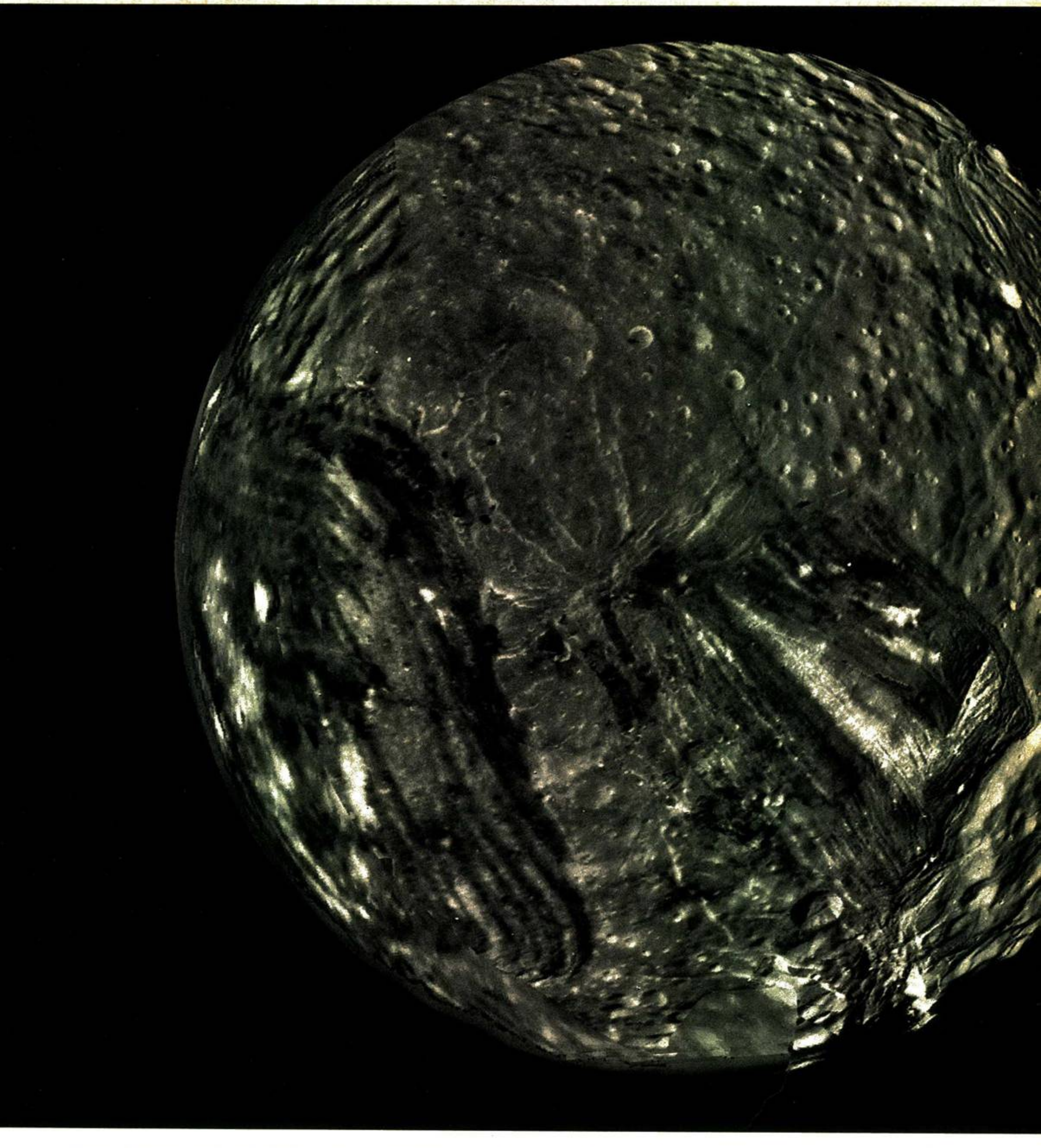
Investigating Triton

Triton is an intriguing moon, not only because of its size (a little larger than our moon in diameter), but also because of its atmosphere, surface composition, and unusual orbit. Current infrared spectral evidence suggests that methane exists as ice on the satellite's surface beneath a nitrogen-methane atmosphere equivalent to possibly as much as a tenth of Earth's atmosphere. In fact, Triton is cold enough for liquid nitrogen to flow on its surface,



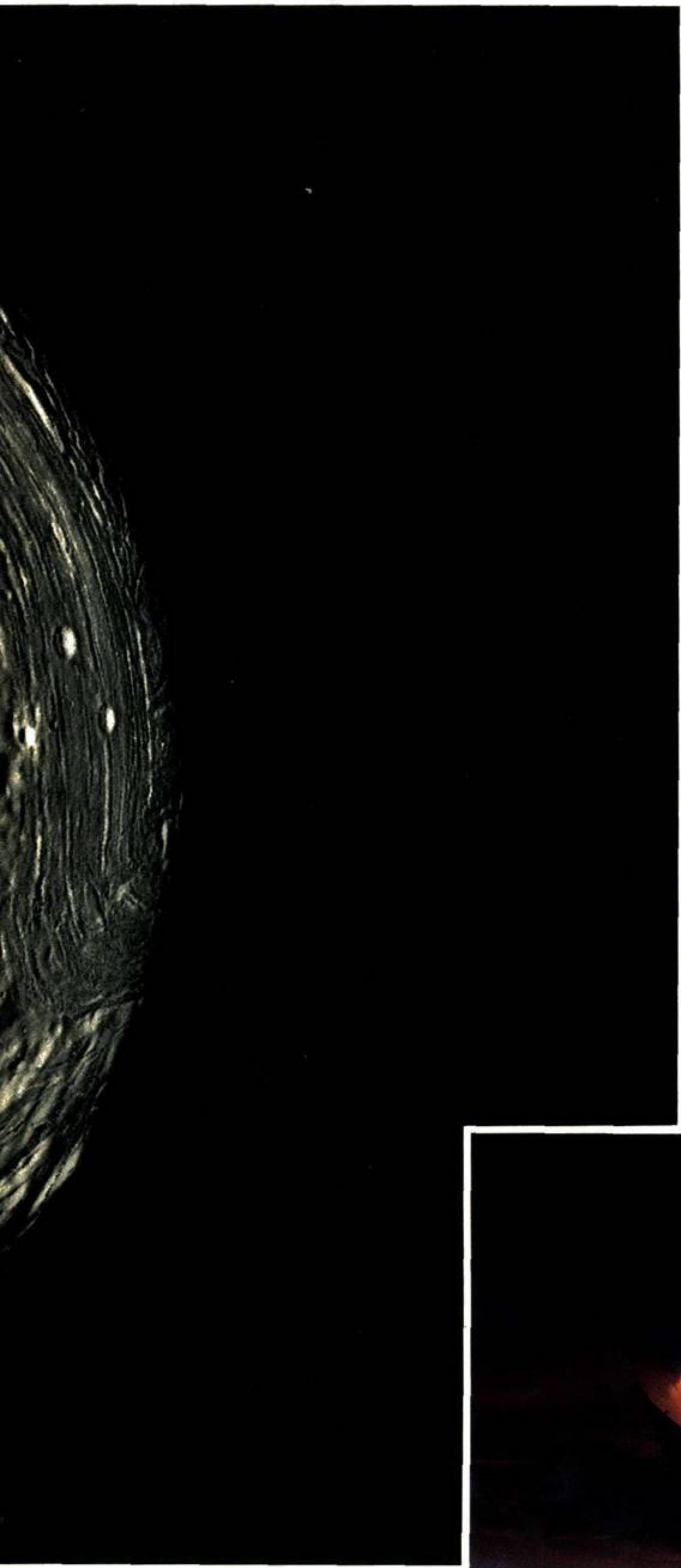
Above: Neptune will be the culmination of Voyager's twelve-year tour of the solar system. Here, the spiral path of the spacecraft can be traced from Earth to Jupiter (July 1979). Saturn (August 1981), Uranus (January 1986), and Neptune (August 1989). The flight paths of Voyager 1 and Pioneers 10 and 11 are also shown.

Left: Voyager 1 took this unique photograph of a crescent Earth and Moon from a distance of 11 million kilometers on September 18, 1977. NASA/JPL photo.



Above: Voyager 2 captured this sharp mosaic of Miranda, a small Uranian world marked with almost every type of terrain found throughout the solar system. NASA/JPL photo.

Right: This 64-meter diameter antenna at the Goldstone Station in California's Mojave Desert is part of NASA's complex of antennas called the Deep Space Network, which maintains daily contact with planetary spacecraft, including Voyager 2. NASA/JPL photo.



perhaps in the form of shallow lakes one meter deep.

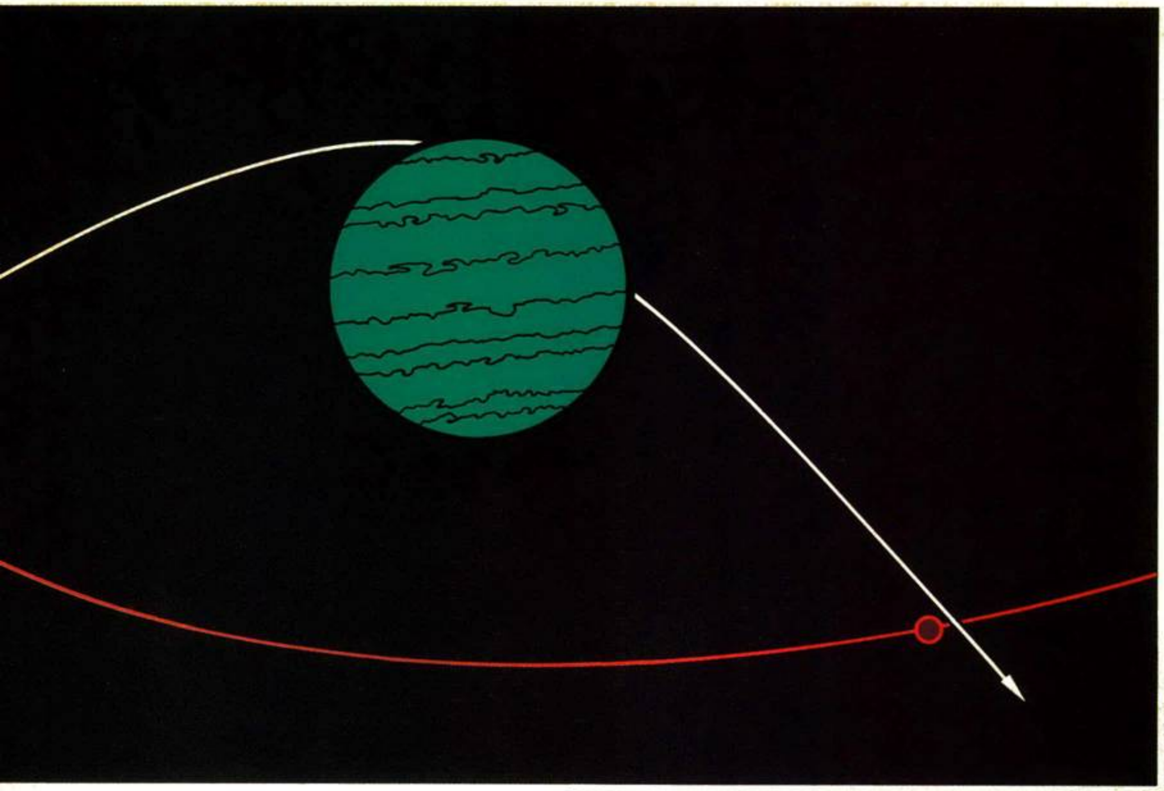
Scientists are especially interested in seeing Triton's surface, which might harbor a rich hydrocarbon sludge of organic molecules. Its reddish color is believed to be due to the photochemical action of sunlight on hydrocarbons in Triton's atmosphere, the same type of action that occurs in the much denser atmosphere of Saturn's moon, Titan.

But our current knowledge of Triton may be somewhat misleading. The most recent estimates for Triton's mass and diameter yield an unbelievable density nearly five times that of water. More probably Triton is either larger than we think — perhaps almost as large as Mercury — or we have overestimated its mass.

Triton orbits Neptune once every 6 days in a circular retrograde orbit inclined 20 degrees to Neptune's equator. In fact, it is the only large satellite in the solar system with a retrograde orbit. Triton's gravity raises a small tidal bulge in Neptune's atmosphere beneath the orbiting moon. This tiny bulge is slightly offset in the direction of Neptune's rotation about its spin axis. But since this offset trails the orbital direction of retrograde Triton, the bulge exerts a gravitational drag slowing the satellite and causing its orbit to decay. Thomas McCord of the Massachusetts Institute of Technology once predicted that Triton will be torn apart by tidal forces less than 100 million years from now when its orbit approaches too close to Neptune. More recent estimates suggest a much longer lifetime for this strange moon.

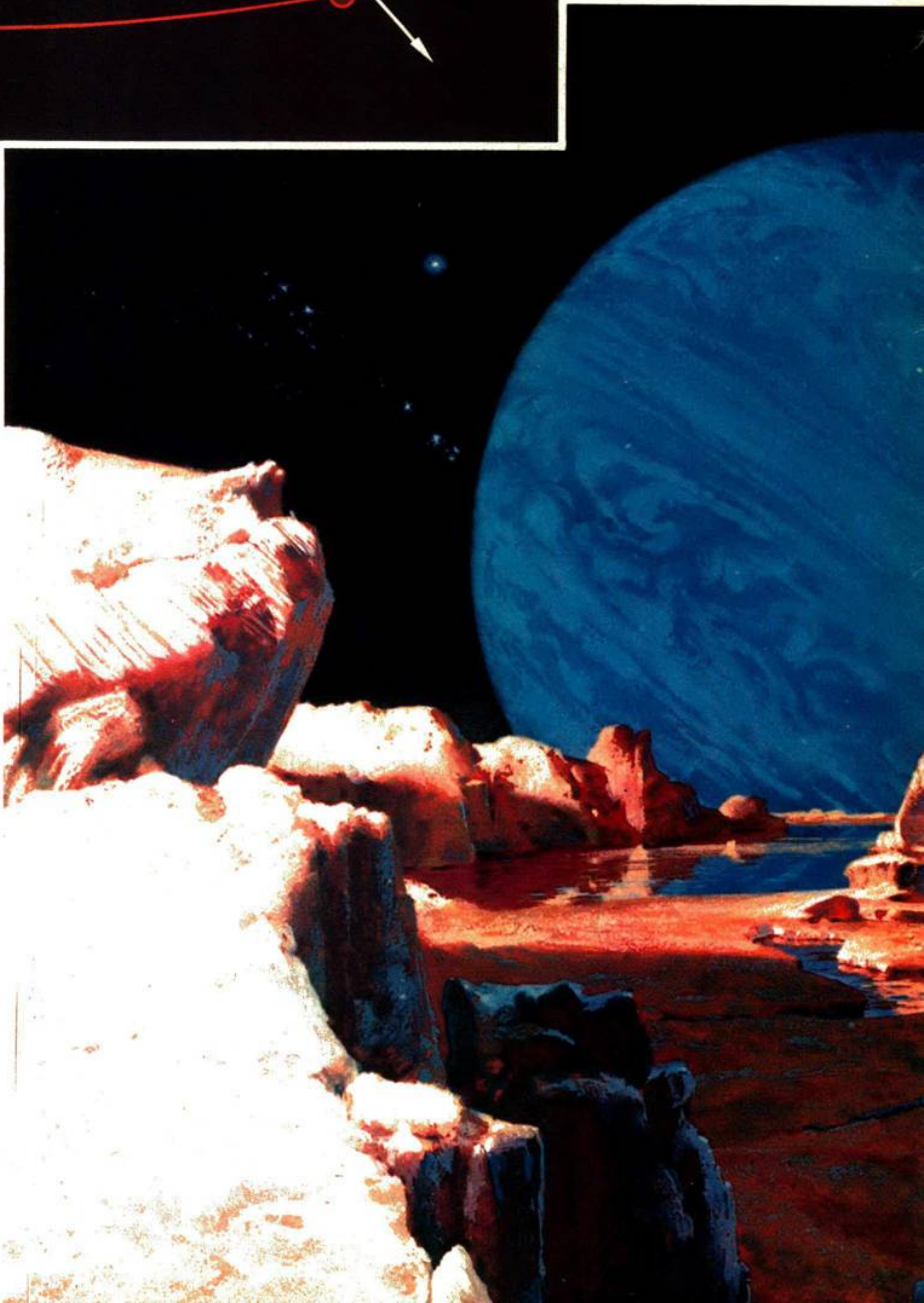
Triton's highly inclined orbit may contribute to dramatic seasonal variations. Each pole spends 82 years in sunlight while the other is in darkness. At the lighted pole, ices of nitrogen, methane, neon, and argon may vaporize, adding to Triton's atmosphere. At the unlighted pole, the atmospheric gases would condense into an ice cap. This alternating shrinkage and growth of polar caps could cause Triton's atmosphere to grow thicker and thinner with its 41-year-long seasons.

Triton's unusual orbit has spawned many theories concerning its origin. It was once believed that a



Above: Voyager 2 will "dive" over Neptune's north polar crown at close range on August 24/25, 1989. The craft will be safely beyond the upper atmosphere as it heads for a Triton encounter some five hours later.

Right: The large moon Triton, seen here in this artist's conception, may prove the show-stopper at Neptune. Larger than Earth's moon, it may have a thin atmosphere of nitrogen and methane with very shallow lakes of liquid nitrogen on a surface partially covered by methane ice. Its reddish hue, like that of Saturn's moon Titan, suggests that sunlight may be breaking down the methane and creating a variety of organic particles in the form of hydrocarbon-based aerosols. NASA/JPL illustration.



cataclysmic event might have flung Pluto out of orbit around Neptune, wrenching Triton into its retrograde orbit. However, the discovery of Pluto's moon Charon put this theory into doubt. It seems unlikely that a satellite would itself possess a moon or could retain that moon during the pair's violent ejection from the Neptunian system.

Perhaps Triton is a captured body. If this is the case, Triton is by far the largest captured body in the solar system. Evidence of tidally induced surface distortions would lend support to the captured-object theory, whereas absence of these signs would evoke other theories. Voyager 2's cameras might be able to settle the argument.

Little is known about Neptune's second satellite. Only 300 kilometers across, Nereid travels in a highly elongated orbit, more so than any other known satellite in the solar system. During its one-year orbit around Neptune it comes as close as 1.4 million kilometers to Neptune, then pulls as far away as 9.7 million kilometers. Nereid may be a captured asteroid or comet.

Engineering Challenges

At Neptune's remote distance, the infamous square-of-distance penalty will challenge Voyager engineers to deal with fainter light levels and weaker radio signals. Daylight levels 900 times fainter than those on Earth are as dim as the break of dawn or the fleeting moments of late dusk on our planet. Engineers will also continue to try to achieve sharper pictures and less image "smearing" due to motions caused by Voyager's attitude control thrusters. Spacecraft attitude rates might be slowed below those achieved at Uranus by further reducing the amount of time that the thrusters fire.

The greater communications range will be compensated by continuing to "compress" the imaging data onboard the spacecraft, as well as increasing the gain of the giant receiving antennas on Earth. NASA's Deep Space Network's (DSN) 64-meter antennas will be extended to 70 meters by adding skirts to each dish and realigning the panels. Also, additional large radio telescope antennas in New Mexico, Australia, and possibly Japan will be "arrayed" with those of the DSN for greater sensitivity to Voyager's faint signals. It is important that everything go perfectly at encounter. After all, a second visit to Neptune may not be in the offing for several decades.

Round-trip communication times will exceed eight hours when Voyager 2 reaches Neptune, leading to three principal concerns. Onboard fault detection and correction will of course be vital to deal with potential problems. Also, since Voyager 2 has lost one of its two radio receivers, flight controllers will have to exercise special care in keeping track of the proper command frequency of Voyager's surviving but degraded radio receiver. And finally the spacecraft's navigators, unable to obtain two-way tracking data from a single tracking station before the spacecraft "sets," will develop a new three-way data type that will enable them to transmit data to Voyager 2 from one station and receive data from the spacecraft at another station.

Selecting the Flight Path

Unfortunately, continuing on to Pluto is not possible. Voyager 2 would have to fly within 4,000 kilometers of Neptune's center to make the necessary gravitationally assisted maneuver that would loop the probe to Pluto. But that gives the mission designers a free choice in selecting the flight path that maximizes the scientific objectives at Neptune. In simple terms, very close Neptune and Triton encounters are ideal. The north "polar crown" aiming zone provides the only solution for these objectives.

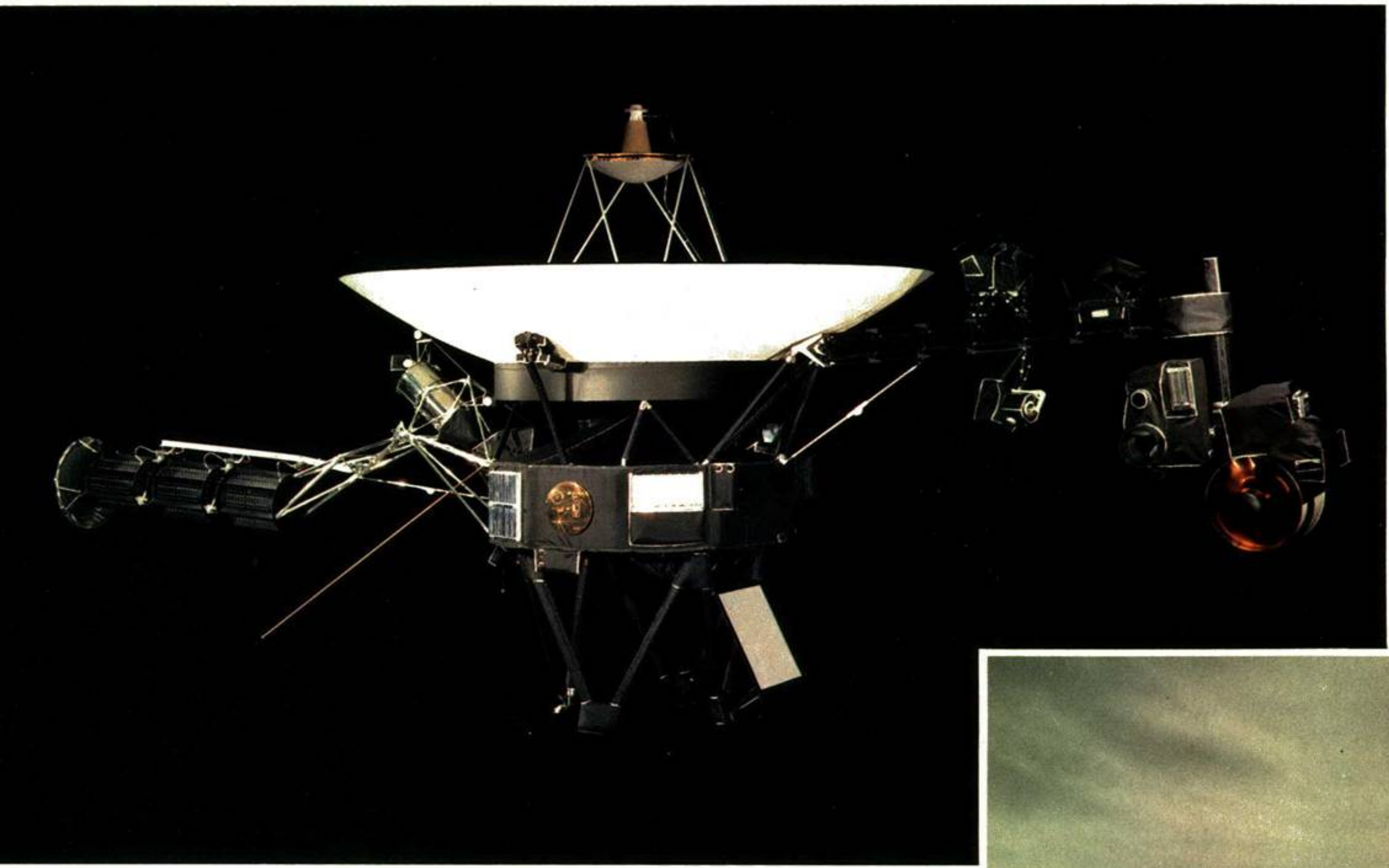
In 1984 a nominal trajectory was designed that would take Voyager within 3,500 kilometers of the top of Neptune's atmosphere, then dive down to fly within 10,000 kilometers of Triton some five hours later. But ongoing ground-based observations and theoretical predictions began to change the best estimates of key Neptune and Triton physical constants. With Murphy's Law living up to its reputation, all of the changes moved in the worst possible direction.

The best estimate of Neptune's mass has shrunk by 1.6 percent, requiring Voyager to fly even closer to Neptune to ensure sufficient downward deflection to reach Triton. Revised calculations placed Triton nearly 8,000 kilometers "down," requiring a swingby 1,000 kilometers closer to Neptune. Finally, Neptune's estimated radius grew by 900 kilometers. In short, the most current nominal trajectory will take Voyager only 1,300 kilometers from Neptune's atmosphere for the north polar crown aiming point.

By themselves, these changes would not present any real problems since the navigation team can deliver Voyager 2 within a 400-kilometer box as long as there is a reasonable supply of optical navigation images. The concern is not that the spacecraft might impact Neptune, but rather that drag from Neptune's upper atmosphere might cause the spacecraft to lose attitude control or suffer other possible unwanted effects. Voyager can be easily aimed farther from Neptune, but the resulting Triton flyby distance will be increased to 25,000 kilometers or more. Another consideration is that the chosen flight path should not pass too close to Neptune's rings.

Everything astronomers know about Neptune's rings is based upon a handful of Earth-based stellar occultation measurements, some of which occurred on only one side of the planet. Philip Nicholson of Cornell University, William Hubbard of the University of Arizona, and other observers have been trying to model these partially filled ring arcs. At the moment there appear to be narrow ring arcs near 54,000 and 67,000 kilometers from the center of Neptune, presumably in the planet's equatorial plane.

By moving the flight path outward to safely clear the upper atmosphere of the planet, Voyager 2 will cross the equatorial plane less than one hour before closest



Above: The Voyager spacecraft with the boom containing its nuclear power generators (left) and the science boom (right) with its steerable platform of optical instruments. A gold-coated copper record containing the recordings of various sights and sounds of Earth is protected by a cover that has instructions on its face (center). The large antenna (top) is 3.66 meters in diameter. NASA/JPL photo.

Right: Four of the twenty-seven 25-meter radio telescopes in Socorro, New Mexico, making up the Very Large Array. These will be used to capture 21,600 bits per second from Voyager 2 during the Neptune encounter. Photo courtesy of E-Systems, Inc.

approach to Neptune at a distance of roughly 69,000 kilometers. The precise location of the 67,000-kilometer ring, though uncertain at present, will be refined as better models are developed. Meanwhile, the Voyager mission designers have developed a "risk assessment plan" and maneuver (path adjustment) strategy to deal with the concern.

A large maneuver to change Voyager's velocity by 21 meters per second was made on February 14, 1986, that will aim the probe over the polar crown, but only 37 of the total 49-hour flight time correction was made. This was done to conserve propellant just in case it should be decided to maneuver to a very distant aiming point from Neptune, one not associated with the north polar crown. However, it is more likely that the main objective will remain the polar crown option, adjusting the nominal Triton flyby distance outward to perhaps 20,000 kilometers, if necessary, to maintain safe passages by the upper atmosphere.

In the summer of 1986, the Voyager mission planners made an intensive effort to model both the Neptune ring arcs and the upper atmosphere, assess the polar crown and nearby aiming point options, and calculate the probabilities of various spacecraft risk factors. These studies are being evaluated in mid-November at the Science Steering Group meeting at the Jet Propulsion Laboratory in Pasadena, California, when the nominal flight plan will be chosen. The matter will not end there, however, as continuing ring observations during the trip to Neptune will be used to further adjust the aiming point, if warranted.

Crossing the Heliopause

After Voyager 2 leaves Neptune far behind, it will join Voyager 1 and Pioneers 10 and 11 in a lonely trek out of the solar system. With a little luck, one or perhaps both of the Voyagers will be alive and well at the crossing of the heliopause boundary, where the interstellar medium restricts the outward flow of the solar wind and confines it within a magnetic bubble called the heliosphere. The exact location of this boundary is not known, but it is believed to be located between 50 and 150 astronomical units from the Sun.

At speeds of roughly 3.5 AU per year, heliopause encounter could occur between 1995 and 2025. Barring a sudden electronic failure, the Voyagers' lifetimes, determined by the declining propellant reserves and nuclear power output levels, could extend to the year 2015. A key objective for astronomers will be to regularly sample the thin soup of energetic particles through which the Voyagers slowly make their way toward the stars.

The Sun spews protons, electrons, helium ions, and a few heavier atoms at speeds of nearly 2 million kilometers per hour. Although several thousand of these particles may be found in each cubic meter of interplanetary space, the density of air is a billion billion times greater. The Voyagers will continue to make daily reports to Earth on the ingredients of this vast and changing particle soup.

The solar system does not end at the heliopause boundary. Well over one light-year farther out lies the outer edge of the Oort Cloud, a swarm of small cometary nucleii barely held in orbit by the Sun's feeble gravity. The two Voyager robots will race past the orbit of Pluto by the end of this decade and past the heliopause boundary early in the twenty-first century. But even at speeds of 60,000 kilometers per hour (about 16.6 kilometers per second), it will take more than 20,000 years for the Voyagers to reach the outer regions of the comet swarm. By this time, they will have traveled 25 percent of the distance to Proxima Centauri, the nearest star.

To the Stars

After the Voyagers have left the remote realm of comets they will begin a forever journey through the Milky Way Galaxy. Though appealing to the imagination, it is extremely unlikely that extraterrestrials will ever discover one of the Voyagers. But it is still exciting to calculate the Voyager flight paths into the distant future, searching for close encounters with other star systems.

In about 40,000 years, Voyager 1 will pass within 1.6 light-years of AC+79 3888, an aging star in the constellation Camelopardalis. Though only one-third the size of our Sun, it could harbor planets. Also in 40,000 years, Voyager 2 will fly within 1.6 light-years of Ross 248, a small star in the constellation Andromeda. Radiation bursts from Ross 248 suggest unfavorable conditions for life-bearing planets. Many other stellar flybys will occur with the passing eons.

The significance of the Voyager missions go beyond scientific discoveries, technological spin-offs, and even national prestige. Early man's curiosity compelled him to leave the caves and explore the world around him. We can only speculate on his simple perceptions during those endless millennia of evolution and emerging intelligence. But throughout recorded history he has followed an unceasing quest to understand himself through contemplation and investigation of the cosmos.

Charles E. Kohlhase is manager of the Voyager Mission Planning Office at the Jet Propulsion Laboratory. During the Uranus flyby, Kohlhase was responsible for planning the major events of the Voyager encounter. He is also the designer of "Wilderness," an expert system simulation for outdoor survival.

Why Can't We E

Like a curious but wary cat, we glide past the little world we are exploring. It shrinks behind us, becoming lost among the stars. Color photographs are broadcast back to Earth that may reveal an irregularly shaped conglomeration of dust-reddened ices no more than a few kilometers across.

A brief burst of our rockets reverses our direction and sends us back toward the icy body. We carefully scout for possible hazards to our delicate and expensive spacecraft.

When we are sure all is safe our engines fire, placing us into an orbit about thirty kilometers from the little world's center. From the speed of our orbit we determine its mass to within 1 percent. Visible and infrared cameras map the surface and determine its temperature.

Weeks pass. The world we circle falls ever closer to the Sun. As the available sunlight increases, solar panels augment our nuclear generator to produce more power, allowing many experiments to begin. The waxing solar heat is expected to make the object quake as ices melt into pockets of gas that explode from the surface.

After long meetings back on Earth and hard decisions balancing knowledge against risks, our orbit is lowered to six kilometers.

A small rocket-powered penetrator shaped like an oversized golf tee leaves its cradle and streaks toward the awakening world. The golf tee buries itself in the ice. For a few hours, before its batteries are exhausted, it broadcasts long streams of data to be relayed to Earth.

We retreat to 10,000 kilometers as our object swings about the Sun. The solar wind has blown gas far behind the evaporating world, and we begin a journey of tens of thousands of kilometers to explore its tail. Later we return to the re-frozen nucleus to conduct a number of experiments for as long as fuel and nuclear power remain.

This is how, until one year ago, the United States had planned to explore Comet Wild-2. Now this most interesting of accessible comets will swing back out of the inner solar system, unexplored. And as a result of bureaucratic budgetary decisions, the future of American cometary research is still very much in doubt.

Our story begins in 1980 when, in response to concerns from NASA management that automated planetary exploration was pricing itself out of

xplore a Comet?

by Donald Frederick Robertson

Illustrations by Greg Kot

NASA
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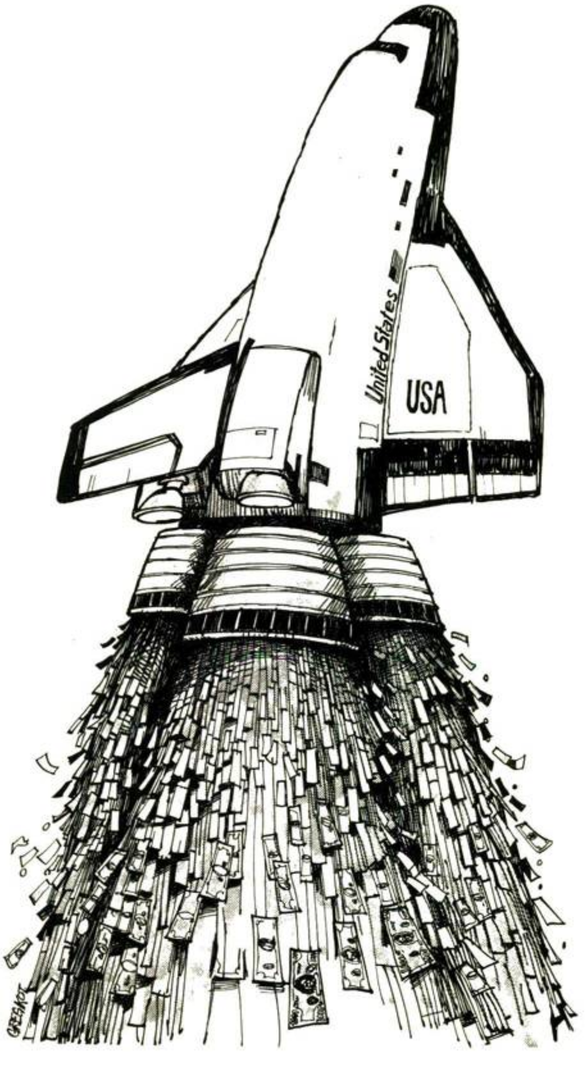
business, the Solar System Exploration Committee (SSEC) of NASA's Advisory Council was created "to formulate a long-range program of planetary missions" that would "realistically reflect the changing fiscal conditions of the 1970s."

There was plenty of room for concern on NASA's part. After the intense exploration of the 1960s, funding for interplanetary missions dried up along with the Apollo program. By the end of the 1970s the only new mission planned was the Galileo Jupiter Orbiter/Probe, and by then even that mission came close to losing its funding.

With the new decade the United States infuriated the Europeans by unilaterally abrogating its half of the Ulysses International Solar Polar Mission. The newly inaugurated Reagan Administration even began to talk seriously about abandoning the Voyager spacecraft, which were already in flight, in order to save the relatively miniscule mission-support costs.

The result was nothing less than civil war within America's space program. Planetary scientists pointed to the Space Shuttle, claiming that this program to develop reusable human space transportation, which was running at about twice its planned budget, was sopping up all the nation's space funding.

Shuttle management responded, reminding NASA that they had said all along that the Shuttle was under-funded and would cost about twice what the Nixon Administration had budgeted for the project. They further argued that the savings to be achieved through reusable space transportation would make possible the kind of planetary exploration we were used to, but at a cost the nation could afford. Finally, if human missions to other planets were ever to be contemplated, the Shuttle, along with a space station, would be essential.



It was in an environment perhaps best described as acrimonious that the SSEC in 1983 delivered its report to NASA describing a plan to cut costs while maintaining an ongoing and scientifically viable program. The key word was "program." Overall costs were to be cut by funding a series of spacecraft, which would permit semi-production line construction and maximum reuse of components and ground support.

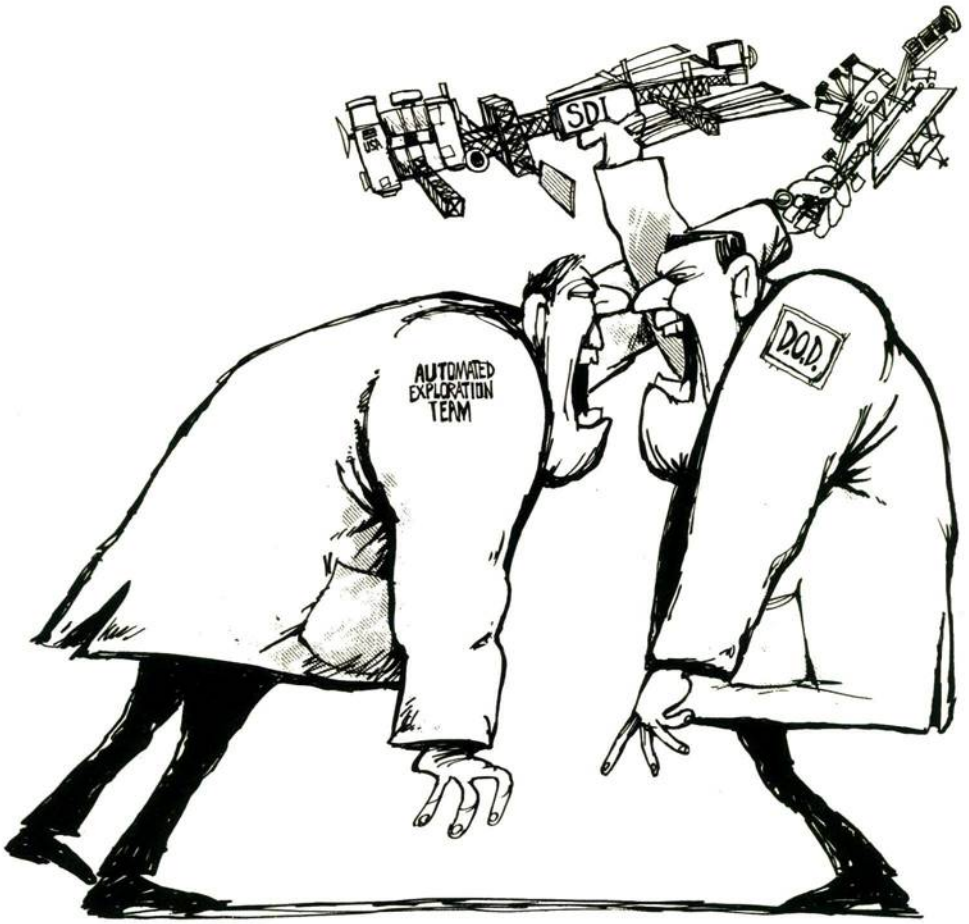
The SSEC also said it was necessary "to set strict priorities" and "to adopt lower cost, innovative approaches to their implementation." However, "NASA and Congress must [also] adopt a fresh philosophy with respect to committing resources for planetary exploration. An emphasis on overall program cost should replace the arbitrary rationing of the rate of new mission activity: the control of mission costs depends upon increasing mission frequency well above the present depressed level so that the economies of heritage in hardware and software can be realized."

The SSEC recommended two concurrent programs. For the inner solar system, a "Planetary Observer" spacecraft was to be adapted from an appropriate Earth-orbit spacecraft (saving the cost of designing a new one), which would be used to answer limited and well-defined questions. There would be no more billion-dollar missions, like Viking, to find out whether or not life exists on Mars. Instead, a series of small missions, each costing a few hundred million dollars, would be sent to various terrestrial planets to investigate questions such as the presence of ice at the Moon's poles and the location of water on Mars.

The SSEC's Planetary Observer program included a Mars Geoscience/Climatology Orbiter mission, a Mars Aeronomy Orbiter, a Venus Atmospheric Probe, a Lunar Geoscience Orbiter, a Mars Surface Probe, and a Near Earth Asteroid Rendezvous. Any remaining funding would be used for "international missions of opportunity."

The entire cost of the Planetary Observer program was to remain under $70 million per year (in 1986 dollar figures, which takes into account inflation since the original report). This was to allow for a new mission every two or three years.

The second ongoing program was to continue the United States' sole exploration of the outer solar system using a new spacecraft called the Mariner Mark-II. Other possible missions included a Comet Rendezvous and Asteroid Flyby, a Titan Probe and Radar Mapper, a Saturn Orbiter (since combined with the Titan mission into the proposed Cassini Saturn Orbiter and Titan Probe), a Multiple Mainbelt Asteroid Orbiter and Flyby, a Saturn Flyby and Probe, and a Uranus Flyby and Probe. The status of these missions is, even today, completely undetermined. They are unlikely to be funded, at least in the near term, because of the Reagan Administration's single-minded diversion of funds into military projects like the



Strategic Defense Initiative (SDI).

The Mariner Mark-II spacecraft would be "capable of simple reconfiguration to undertake all [the SSEC-recommended] missions beyond Mars . . . [requiring] a *modular* spacecraft with ample design . . . margins coupled with a multi-mission ground support system." New technology would be used only to cut costs, not increase performance beyond that absolutely required for the mission.

The new spacecraft would use the most successful technology. Its power module would be able to accommodate either nuclear or solar power sources, and the propulsion module would provide for the addition of fuel tanks necessary for these missions.

Equipment left over from earlier missions would be used to the extent possible. A Voyager high-gain antenna would be placed on the Titan Radar Mapper, and the Comet Rendezvous and Asteroid Flyby (CRAF) mission would use Viking fuel tanks and antennae, Voyager electronics bays, and Galileo nuclear power units. Mariner Mark-II missions were budgeted at about $150 million per year.

Since one of the greatest weaknesses in American planetary exploration has been actual analysis of the data obtained in a mission, the SSEC further recommended that a steady funding of about $70 million per year be allocated to mission operations and data analysis. To ensure a steady supply of new technology, which often can help to cut costs, the SSEC also recommended that a similar amount be spent on research and analysis.

Thus the entire planetary exploration program was to be kept under $360 million per year. The SSEC said that "although this amount is many times *less* than historical highs for the [planetary exploration] program, the anticipated [scientific] yield is comparable to that of the 1970s when planetary exploration enjoyed a golden age."

A third class of missions was identified but not recommended. This "Augmented Program," to be undertaken when the nation could afford it, would consist of ambitious, technologically demanding — and expensive — missions such as a Mars Sample Return, a Titan Rover, and a Comet Sample Return.

The SSEC plan should have been a shoe-in. It had all the elements of a perfect political compromise. The Reagan Administration held this plan before the rest of the scientific community as an example of how they believed good science would work under a tight budget. (Budget Director David Stockman was quoted, however, as saying the last thing the government needed was another "entitlement program.") NASA had kept the planetary scientists satisfied while getting the Shuttle program to fly.

But the plan was not approved by the Administration because money wasn't available. Although the Administration and Congress declined to grant the "entitlement" aspects of the program — constant funding of the program as opposed to mission-by-mission funding — at first it seemed as if the individual missions recommended by the SSEC would be funded. The first two Observer missions — the Venus Radar Mapper and the Mars Observer Geoscience/Climatology Orbiter — were both approved and were the first planetary mission starts since Galileo was approved in 1978. And the Mariner Mark-II spacecraft is far along in planning stages at NASA's Jet Propulsion Laboratory, as is the development of advanced cameras and other instruments for it to carry. But because its funding is either continued or denied on an amortized, year-by-year basis under the Reagan plan, the money it needs may run out.

The Jet Propulsion Laboratory, which manages the United States' automated planetary missions along with parts of the NASA bureaucracy, asked NASA for the CRAF mission in the Fiscal Year 1987 budget. But late in 1985, *Aviation Week and Space Technology* revealed that NASA Administrator James Beggs had decided not to ask the Reagan Administration for CRAF in 1987. Instead Beggs requested an international mission called Topex to map the topography of Earth's oceans and the International Solar Terrestrial Physics program to map Earth's radiation fields. *Aviation Week* speculated that the decision was made because both of these missions were international at a time when NASA was trying to get international help for the Space Station.

Military considerations may also have played a part in the decision. Accurate maps of ocean topography are important for submarine-launched ballistic missile targeting, and an improved knowledge of the radiation environment in Earth orbit is high on the Strategic Defense Initiative's list of priorities.

Be that as it may, in early 1986 the planetary science community felt nothing less than betrayed. In response to the Reagan Administration's wishes, they had abandoned their ambitious plans in return for what they saw as a commitment to ongoing — if limited — exploration. But by late 1985 the program was completely abandoned.

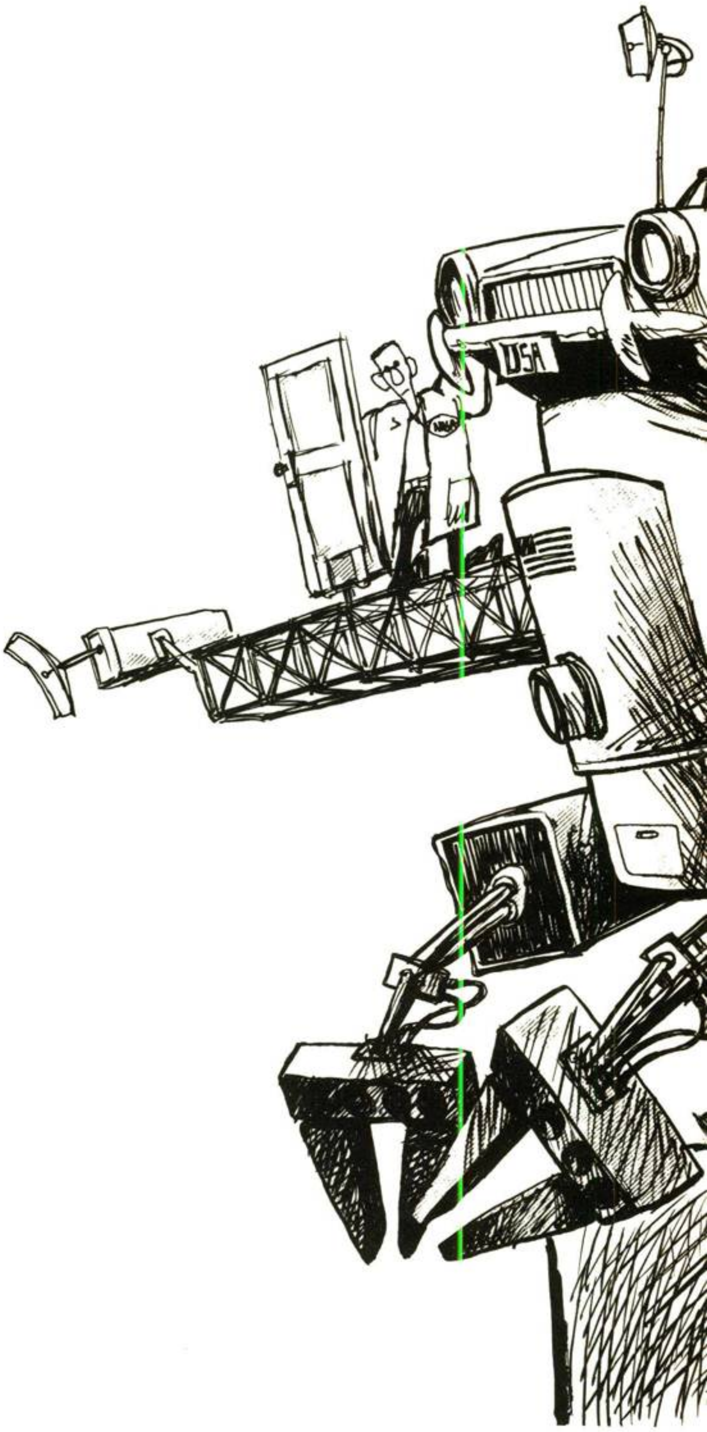
A number of planetary scientists took what had been a battle largely confined within NASA to the public. Laurel L. Wilkening, vice president for research at the University of Arizona, and David Morrison, acting vice chancellor for research at the University of Hawaii and chair of the SSEC, jointly wrote and distributed a press release extremely critical of NASA's decision to omit the CRAF funding.

Wilkening said she "read with dismay the announcement that . . . once again the U.S. is passing up an opportunity to initiate its exploration of comets and asteroids. . . . Unfortunately, this only continues a tradition which was begun in the 1970s in which NASA repeatedly passed by opportunities to send spacecraft to the comets, including Comet Halley at its current apparition."

Morrison was even more forthright. "This failure to proceed with the comet mission suggests the apparent abandonment of an orderly, well-planned, low-cost program for planetary exploration that NASA had previously supported."

After describing the SSEC plans for Mariner Mark-II development, Morrison continued: "Without this spacecraft and the missions based on it, the SSEC plan cannot become a reality. [1986] is a critical year for Mariner Mark-II development, because the most talented and experienced engineers and technicians will be available as a result of the completion of development of the Galileo mission. . . . Delays in a new start for the comet missions seriously jeopardize the optimum usage of these unique human resources and will inevitably increase the costs and risks associated with later development of new planetary spacecraft."

Bert Edelson, NASA's associate administrator for space science (who, according to Wilkening, actually made the decision), responded immediately by telling the American Astronomical Society that CRAF's rejection "had nothing to do with its scientific merit or its technical readiness; it scored high on both counts in the reviews last summer [1985]. The problem was simply that there were equally high

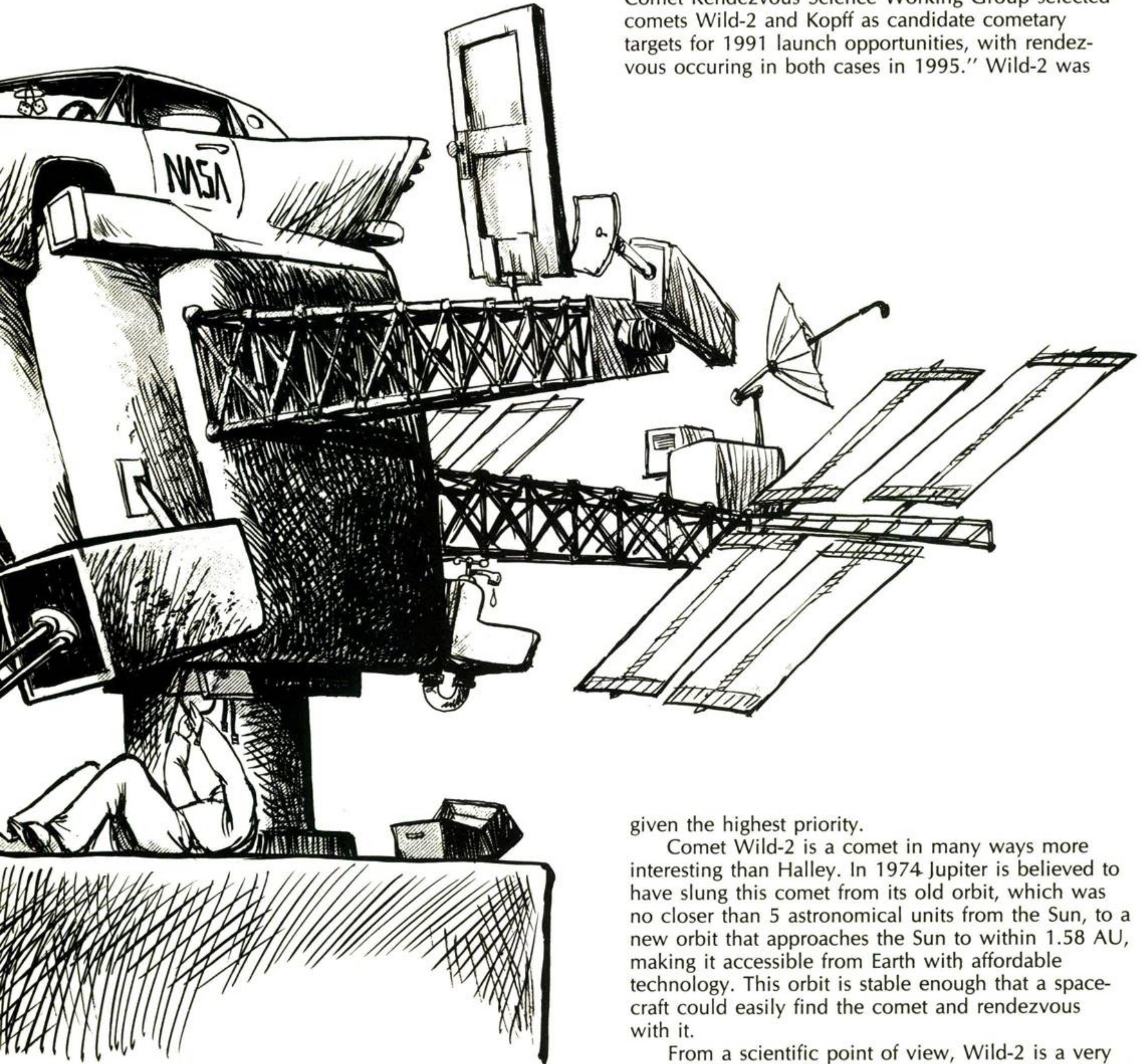


priority missions which, for programmatic reasons, needed to be started now. . . . I intend to make CRAF a top priority new start candidate for Fiscal Year 1988."

Roger Bourke, advanced programs manager in NASA's Solar System Exploration Division, told ASTRONOMY, "The fact is, there is a great deal of disappointment. Nevertheless, we're working hard to make CRAF a highest priority" for 1988.

Besides Morrison's concerns about keeping JPL's resources intact, there is the matter of orbital mechanics in the solar system. When the United States decided to abandon the chance to fly past, let alone rendezvous with, the most active comet with a known, stable orbit — Comet Halley — a new comet had to be found.

NASA management looked for a chance to encounter a comet at least 1,000 days before its closest approach to the Sun, according to John Devlin of the Space Science and Applications Division at NASA Headquarters. This was to ensure that astronomers could view the entire period during which the comet was becoming active. Furthermore, at least one asteroid flyby must fit into the orbit that the spacecraft would follow from Earth to the comet. In the words of the CRAF "Request for Proposals" (a document sent to scientists who may wish to propose experiments for the mission), "The result of applying these [and other] criteria to [all known comets approaching the Sun] in the mid-1990s was that the Comet Rendezvous Science Working Group selected comets Wild-2 and Kopff as candidate cometary targets for 1991 launch opportunities, with rendezvous occuring in both cases in 1995." Wild-2 was given the highest priority.



Comet Wild-2 is a comet in many ways more interesting than Halley. In 1974 Jupiter is believed to have slung this comet from its old orbit, which was no closer than 5 astronomical units from the Sun, to a new orbit that approaches the Sun to within 1.58 AU, making it accessible from Earth with affordable technology. This orbit is stable enough that a spacecraft could easily find the comet and rendezvous with it.

From a scientific point of view, Wild-2 is a very rare and lucky find because it has both an established orbit and is "fresh." Many of the low melting point ices that can give scientists information about conditions in the forming solar system may still be present on Wild-2.

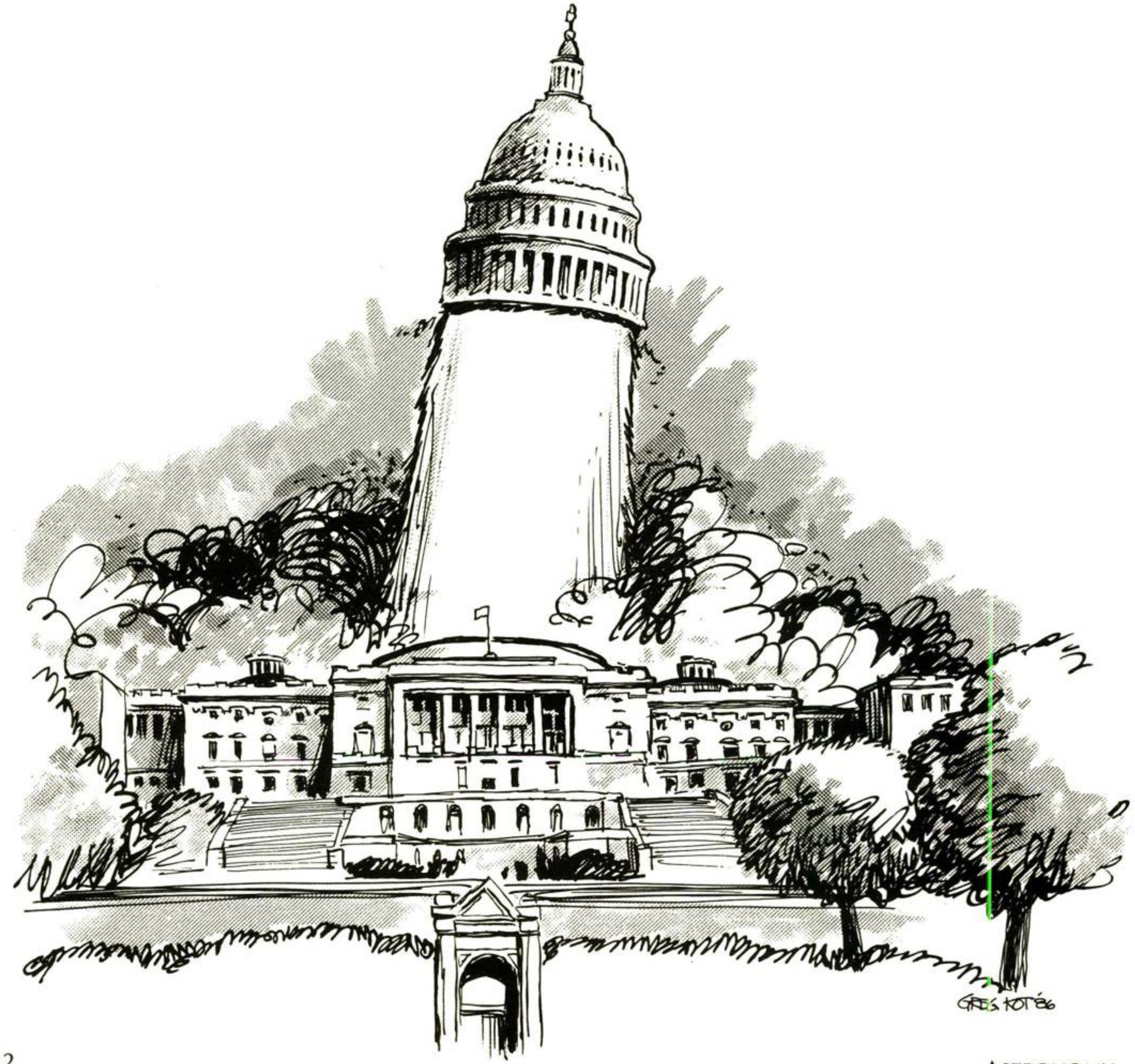
The problem is that to achieve the 1991 launch necessary to reach Wild-2 during its next pass through the inner solar system, CRAF construction must start in 1987. But at the moment, the CRAF mission is in limbo because of a lack of funds.

If CRAF is started in 1988, as is probable according to NASA, the opportunities for a 1992 launch are Tempel-1 and Tempel-2, neither of which is as "fresh" as Wild-2. Worse, both require what is called a Delta-Vega trajectory, which uses a flyby of Earth two years after launch to give the spacecraft the velocity needed to reach the comet. A Delta-Vega trajectory increases the complexity of the mission and the length of time it will be in space — and thus its cost.

A JPL engineer, who talked to ASTRONOMY on the condition he not be identified, said the CRAF mission will require approximately twice the fuel a CRAF mission to Wild-2 would have needed. This makes it difficult to use surplus Viking fuel tanks and impossible to use the light-weight Viking propulsion module structure. This will further increase construction costs, although they will be somewhat offset by West Germany's offer to provide the propulsion module in exchange for part of the experimental payload.

Thus, by delaying CRAF one year, NASA has increased its cost and at the same time reduced the mission's scientific value. Nonetheless, after the current Shuttle confusion clears, NASA hopefully will regain its old momentum and again stand confidently as an innovator in space exploration.

Donald Frederick Robertson is a freelance science writer living in Mountain View, California. His last article, "Space Science After Challenger," appeared in July 1986.



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ASTRONOMY Forum

Mean Skies: One Night in the Life of Arnold Jerrold

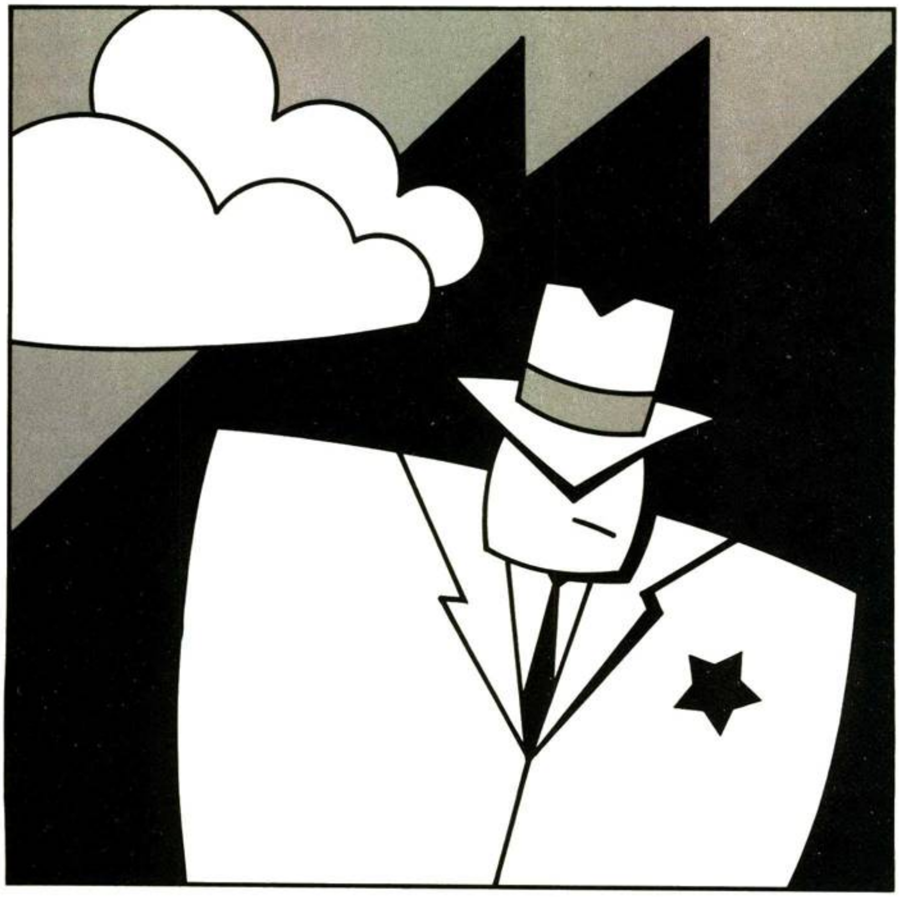
The story you are about to read is true. Only the names have been changed to protect the innocent.

The day: August 6, 1982. The time: four in the afternoon. My name is Arnold Jerrold. My job is to capture the living essence of Comet Austin as it streaks across the night sky. I'm a beat astronomer. It's a dirty job, but someone has to do it.

I pick up my parka and head for The Laboratory. The Sun has raised the temperature to 80 degrees. The people sunning themselves on the campus lawn stare at me openly. I guess they can tell I'm a beat astronomer.

The air conditioning in The Laboratory hasn't worked since 1967. It doesn't matter. In the pursuit of science you make the sacrifices necessary to get the job done.

I'm the first one into The Lab. I hang my parka on my spot on the coat rack. The unwritten code of The Laboratory says this particular hanger is mine, the one between my boss, Dr. Aloisious Thompson, and his graduate student, Jillian McCafferty. I glance at my watch: ten after. McCafferty will be in soon.


Todd Graveline

As if on cue, McCafferty strides confidently through the door. She is a small woman. I might even call her slightly built. Except for that invisible inner strength, she's not the kind of woman you'd expect to be a beat astronomer. She's my partner. Words don't pass between us, just that knowing look.

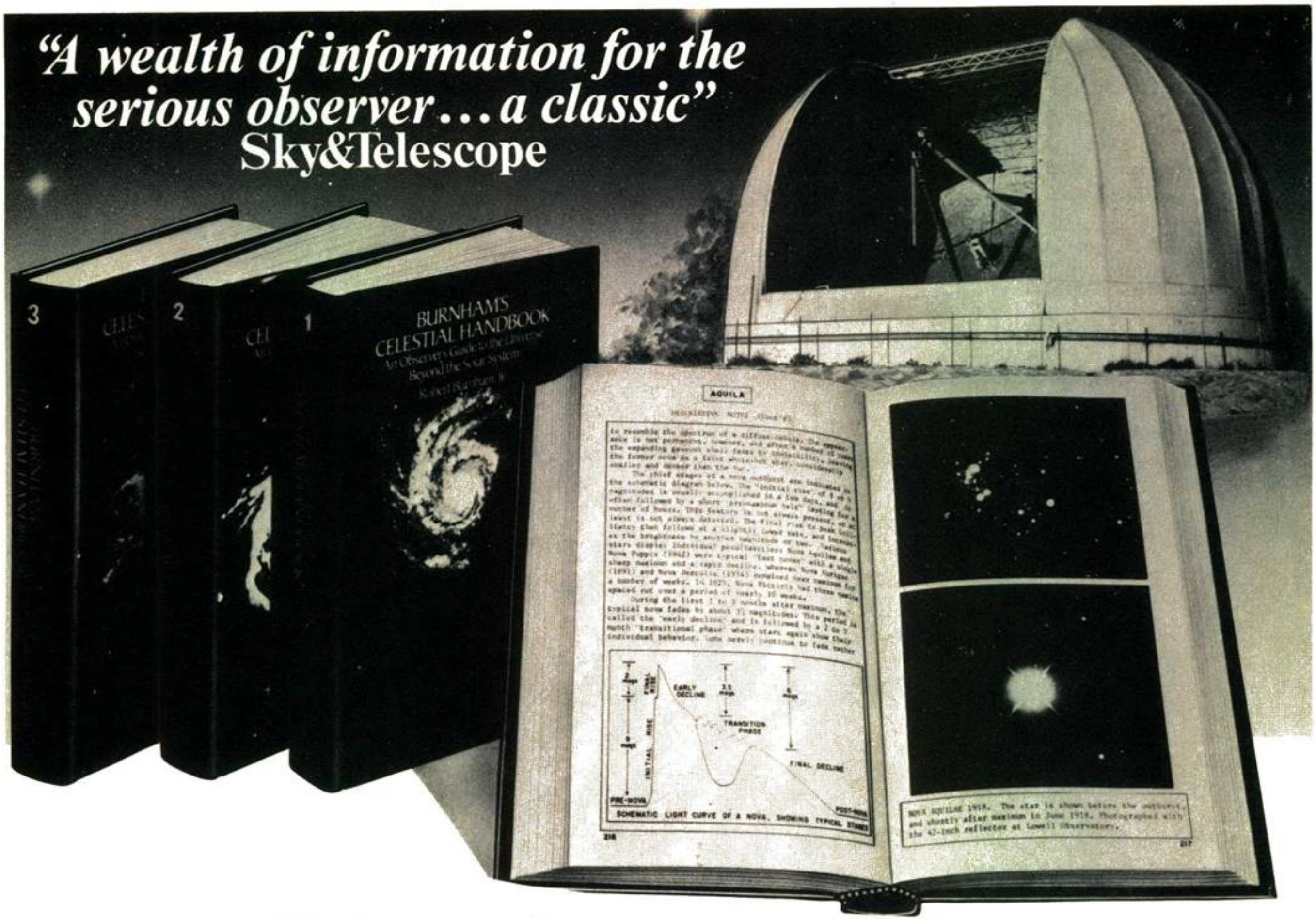
We each start going about our tasks. McCafferty checks the film she will be taking up The Mountain. She makes sure the ephemeris is in the observing box and checks the manual control for the camera.

Dr. Thompson enters The Laboratory. He's a big man with the haunted look one gets after years on the beat. Point to a star in the night sky, he'll name it; wave your hand across a wide swath of the Milky Way, he'll name every constellation in it. It can be frightening, this glimpse into the future — what science can do to you. Sometimes it isn't pretty.

McCafferty and I know the word is coming even before Thompson tells us to load the Bronco and get going. It's going to be a long night.

Our first stop: the grocery store. We head to the frozen foods. Thompson selects a roast beef dinner, McCafferty selects a chicken pot pie. I take turkey. Thompson selects a package of frozen waffles, in case we have to spend the night on The Mountain. His eyes ask, "Do we have syrup?" Mine answer, "Of course." McCafferty fixes me with an icy stare. The syrup has been on The Mountain since 1974.

We finish provisioning with Fig Newtons and Pepsi. The Pepsi will be warm long before we consume it. Fig Newtons and warm Pepsi at four in



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the morning — it's the unwritten code of the beat astronomer.

The drive to The Mountain is uneventful. Storm clouds threaten on the horizon. We briefly wonder whether the night's observing should be aborted. Of course not.

Ten miles of tortured dirt carved out of the side of the mountain by an army of men equipped with bulldozers and explosives. That's The Mountain Road. Every summer the men return to torture The Road again. Every winter the elements try to restore The Road to its pristine condition. Now we travel it.

We arrive at the 9,500-foot level on The Mountain. The Sun has begun its rapid slide toward the western horizon. Storm clouds threaten in the west. Somewhere out there The Comet awaits. Nevertheless, Thompson stops the Bronco near the patch of wild raspberries that cling to a precarious slope on the side of The Road.

We get out.

It is the unwritten code of The Observatory that we pick the raspberries when they're in season. If we didn't pick the raspberries on the way up, we would have to pick them on the way down — at five in the morning, by the light of the Bronco's headlamps.

Thompson charges down the steepest part of the roadbed to the raspberry bushes below. He maintains that the best grazing is beneath the level of the casual pickers. McCafferty and I stake out our grazing territories. The Road is quiet. The air is cool and refreshing. The sounds of nature mingle contentedly with the sound of the scientists munching raspberries.

We are sated by half past six. We continue the journey up the tortured road to The Observatory. When we reach it, the clouds have moved closer. They lie a few miles away, waiting for the opportunity to pounce.

We share The Mountain with another group of scientists. These poor, underprivileged souls spend their time probing the secrets of thunderstorms. Over The Observatory's radio we hear their excitement as the storm inches closer to their instruments. It is sad when a fellow scientist drools over the approach of a thunderstorm.

I bring Dr. Thompson's attention to the poor state of repair of the lightning rods on The Observatory. Two are broken off at rooftop level. One is broken off at ground level. The final one is bent almost double so that its end is only inches away from the control valve for our 300-gallon butane tank. Thunderstorm researchers try to trigger lightning. They are usually successful.

I am a beat astronomer. I am also an undergraduate. Undergraduates are expendable. I go onto the roof.

McCafferty hands me one end of a broken guy wire. I gently and firmly pull on it and the lightening rod begins returning to an upright position.

The wind whistles about me and my hands turn numb on the cold metal of the lightning rod. Lightning crashes in the distance. When the lightning rod is straight, Thompson and McCafferty turn to the shattered guy wires. I hold the lightning rod in place while they repair the guy lines. The first needles of freezing rain sting my cheek. My eyes are watering and I can feel the electric field increasing in the vicinity of the lightning rod.

I urge McCafferty to hurry. She complains that her hands are cold and she is having trouble with the wrench.

I wonder if my flesh is frozen to the rod.

If lightning strikes now, I'll make an interesting roof ornament. Since I won't be able to punch out, I'll be making a decent paycheck. Twenty-four hours a day, seven days a week at minimum wage comes to $29,346 a year.

The lightning rod is secured.

We go inside. McCafferty makes coffee. At 10,000 feet, water boils at a low temperature. McCafferty's coffee is not hot. She complains. Lightning crashes nearer. The Comet is hiding behind a cloud. The storm moves closer. We prepare our dinners. The storm arrives at The Mountain.

Lightning crashes. Our fellow scientists drool over their instruments. It is not safe to venture outside. We stand in the doorway of The Observatory and watch the pretty lightning.

The storm ends. Clouds still sit on The Mountain. Thompson calls our fellow scientists and implores them to move their clouds. They say they will comply. The clouds do not move. We decide to go home.

The fog is so thick you could cut it with a knife. We do not have a knife. Thompson cannot see to drive. I am a sophomore. McCafferty hands me the flashlight. I get out of the Bronco. I walk ahead of the Bronco. I find The Road. I am a seeing-eye sophomore.

It takes us an hour to travel two miles down The Mountain Road. The fog lifts when we reach the 8,000-foot level. I am allowed back in the Bronco. We are below the raspberries. We go home.

We travel this road nightly. Now it's Comet Austin. Later it will be Comet Halley. We are the Comet Patrol. There are lots of comets.

I wonder if I'll develop Thompson's haunted look. But then, there is no sacrifice too great for a dedicated scientist — a beat astronomer.

Gerald A. Arnold
Socorro, NM

An Interview with Astronaut Joe Allen

Joe Allen joined NASA as a scientist-astronaut in the summer of 1967, just six months after the Apollo I crew was killed on the launch pad at Kennedy Space Center in Florida.

Allen, who has a doctorate in physics from Yale University, was working on the sidelines throughout Apollo as tragedy turned to triumph. Throughout nearly twenty years of service at NASA, Allen completed a variety of assignments both at Johnson Space Center in Houston and at NASA Headquarters in Washington, D.C. Prior to his first space flight in 1982, Allen served as a support crew member for Apollo 15 and as the entry CAPCOM on STS-1, the first orbital test flight of the Shuttle.

His first assignment was as mission specialist on STS-5, the first operational flight of the Shuttle. Launched aboard Columbia in November 1982, Allen and his crewmates completed eighty-one orbits in 122 hours and were the first to successfully deploy two commercial communications satellites from the Shuttle's payload bay.

On November 8, 1984, Allen was launched into orbit a second time with crewmates Captain Fredrick H. Hauck, spacecraft commander; Commander David M. Walker, pilot; and mission specialists Anna L. Fisher and Commander Dale A. Gardner.

The flight, designated STS-51A, was one of the most ambitious Shuttle missions. After deploying two communications satellites, Canada's Anik D-2 and Hughes Aircraft's LEASAT-1, the five-member crew carried out the first space salvage operation in history, retrieving the Palapa B-2 and Westar VI communications satellites that had failed to achieve orbit after being deployed from Challenger in February 1984.

Allen talked to ASTRONOMY *early last year about the historic satellite rescue mission.*

ASTRONOMY: You were assigned to your second space flight in August 1983. The flight was originally scheduled to fly in August 1984 and was to have carried several communications satellites into orbit. Did the character of the mission change in February 1984 when the Palapa and Westar satellites failed to make orbit?

Allen: It certainly did. Both satellites had failed to reach their proper orbits.

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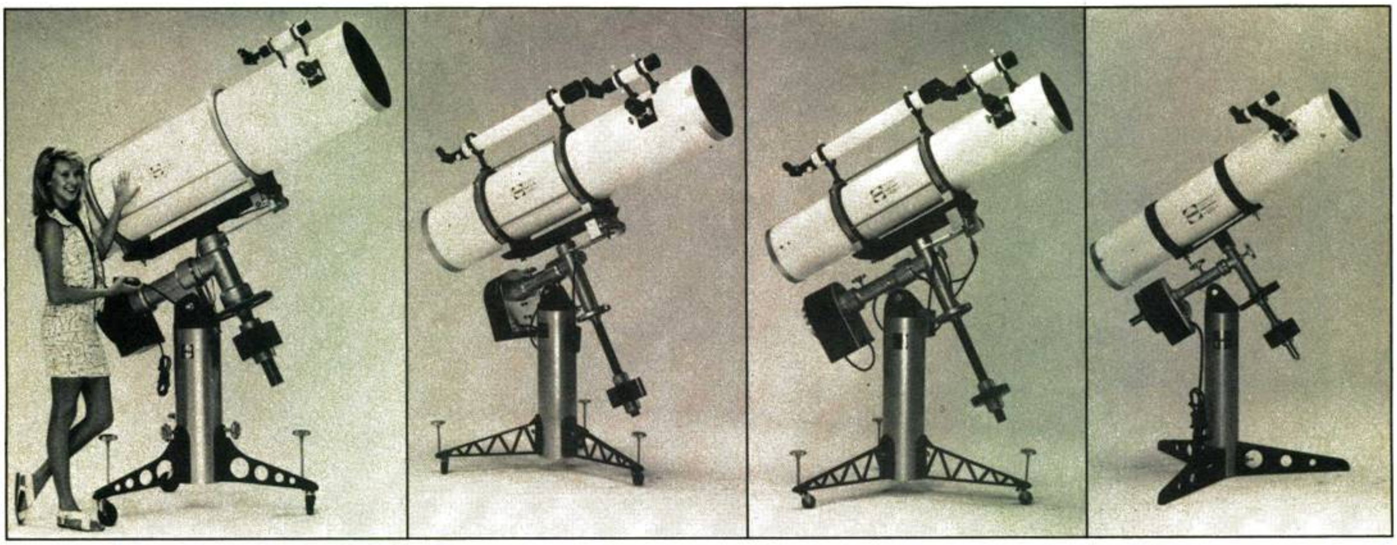

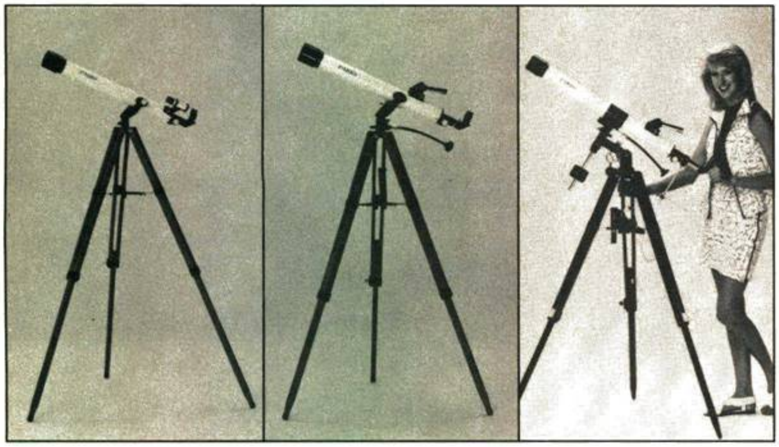

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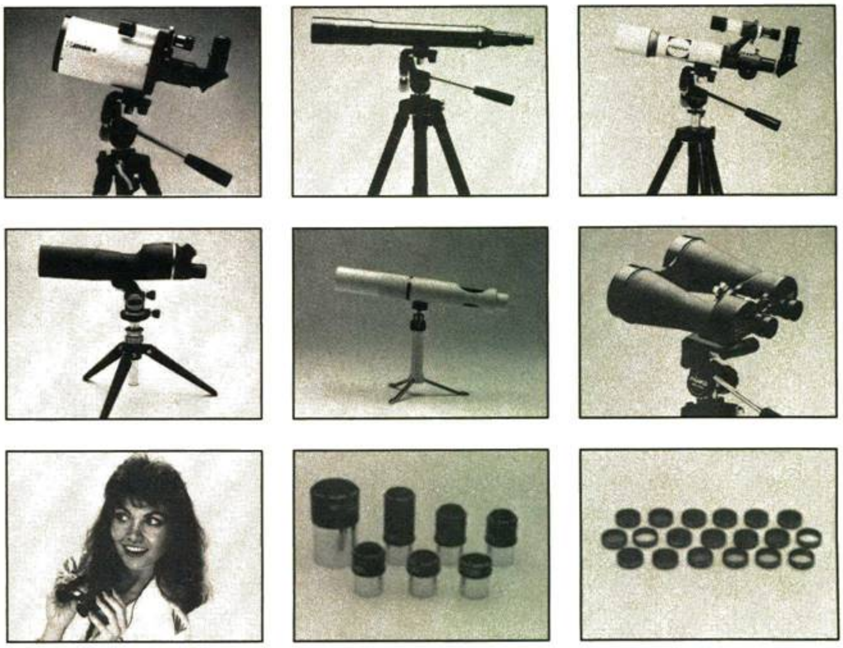

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Ironically, the day after Palapa was lost, an impressive test was underway from Challenger. That was the Bruce McCandless–Bob Stewart test of the manned maneuvering unit, or MMU. Almost immediately, in looking at the very negative satellite results and the very positive backpack results, those of us on the ground were struck by the idea of using the backpack to capture the satellites.

ASTRO: So spacecraft engineers began to think about the problem of retrieving the satellites?

Allen: Yes. Within about a month and a half we had a simulation set up to see whether a space-suited astronaut could fly up to a Palapa-like satellite, and if so, was there any way to grab it. The simulation showed that if we were given the proper tools, it looked possible. Next, we began to invent the tools that would be necessary and we began to design the simulations that would give us practice in using these tools.

Simultaneously, an equally important effort, unique to this particular mission, was undertaken. A large group of business people, lawyers, government officials, bankers, and insurance underwriters, that owned these pristine but totally useless satellites, began working on the agreements and contracts that would be required before retrieval could be attempted. These two groups of people attacked their individual problems without any guarantee that the other group could be ready in time. But each group had to have faith that its efforts would not be for naught.

ASTRO: What were the chances of success?

Allen: We didn't know. But by September 1984 we had tested equipment and developed the procedures to use. Believe it or not, the final agreements to retrieve the satellites were consummated in September. Each group had done its homework and completed its assignments with a little time to spare before the November mission.

ASTRO: Could you describe some of the preparation you underwent prior to the mission? Were you worried that you had taken on too much, too soon?

Allen: That was certainly a potential pitfall that could have stopped us. It looked from a technical point of view that, given enough time, the preparation for a satellite retrieval would be possible. The great worry was that there was just not a lot of time to design, build, and test the equipment. Normally it would have been a two-year undertaking, but we did the whole thing in about six months.

ASTRO: What was the hurry?

Allen: First of all, it was a matter of scheduling. We had to fit the mission into the NASA manifest, that is, into the schedule of flights taking place. These manifests are normally laid out two years in advance. There was a gap around October or November 1984 into which our flight had to fall. Secondly, it was a matter of economics. The longer those satellites were up there, the less sense it made financially to bring them back.

ASTRO: And you needed time for training?

Allen: We did. We simulated the retrieval procedures over and over again at the Martin Marietta Company in Denver. In this simulator we practiced docking with the satellite hundreds of times as though we were in the weightlessness of space. We also did some simulations in the water tank at Johnson Space Center — a large swimming pool that accommodates a person in a space suit. suit.

Finally, we practiced using a simulator at JSC that was strictly a computer-driven video game. Part of the game gets "played" by flying an MMU from the aft flight deck of the orbiter to a satellite. The rest of the game is played from a mock-up of the MMU with that astronaut looking at a display of the orbiter and the spinning satellite. The astronauts on the flight deck can move the robot arm over to the EVA crewman and satellite, or can fly the orbiter over to the crewman and satellite using the proper orbiter controls.

ASTRO: How many crew members were trained?

Allen: Five. Rick Hauck, flying the spaceship, would stationkeep on what he saw out the window while Anna Fisher operated the arm. At the same time, either Dale or I would be flying the MMU. In this simulation we could "dock" with the satellite and we could see the orbiter coming up toward us. All of this was done through the computer-driven visual display.

ASTRO: Did you also talk to the astronauts who had already flown an MMU?

Allen: Yes. From them we knew that it was entirely possible to fly the MMU up to a moving object smoothly and with great accuracy and to steer the MMU and guide ourselves nicely up to a spinning satellite. We also knew from past experience that if you have an automatic device that is going to do the capturing, you better make sure that you have a manual backup to it.

ASTRO: We understand that the satellite orbits needed adjusting, too?

Allen: While we were occupied with our training, Hughes Aircraft satellite controllers completed some very difficult maneuvers crucial to the successful completion of our mission. They circularized the satellites' rather eccentric orbits by firing the apogee kick motors. Then they fired by ground command the hydrazine thrusters and, little by little, lowered the satellites from about 600 miles down to a 200-mile-high, Shuttle-compatible orbit. In a final masterful maneuver they also were able to de-spin the satellites from 50 revolutions per minute down to 2 r.p.m., so that we could safely approach them and wouldn't tumble head over heels once we made contact.

ASTRO: What about the Palapa retrieval? Once the Shuttle was in orbit, the next major step was to rendezvous the spacecraft with the satellite, correct?

Allen: Yes, and it was very difficult to do. It was a game of celestial cat-and-mouse that extended over several days and thousands of orbital miles. Rick and Anna, working together as a team, completed a number of engine burns and were able to bring the 200,000-pound Discovery up to the 1,200-pound satellite. Rick was then able to maintain his position, just thirty-five feet away from Palapa.

It was at that point that Dale and I went outside. The procedure was for me to fly the MMU out to the back of the satellite, dock with the satellite using the stinger, and then stabilize it with the MMU. Then Rick would come close enough to me with the orbiter so that Anna could reach me with the robot arm and grab the grapple fixture attached to the stinger.

While she held me and the satellite, Dale would put a second attachment called the A-frame over the top of the satellite. The one drawback with the stinger concept was that we would grab the satellite from the wrong end, i.e., the end where the adapter was supposed to go. We fully realized that, but that end was by far the easiest place to grab onto the satellite, and once we got a hold on the satellite we certainly didn't want to let go of it again. We had to figure out a way to hold it from the top, and that was what the A-frame was for.

While I was still in the MMU, Anna would hold me and I would hold the satellite as Dale attached the A-frame. Then Anna would let go of me and I was to spin the satellite around 180 degrees. She would now grab on to the new holding point, the A-frame. And once she had it there I would pull myself away and park the MMU. Dale and I together would then fasten the adapter on the bottom end of the satellite while Anna was still holding on at the top. The last step was for Anna to lower the satellite and the attached adapter down into the holding device mounted inside the Shuttle's cargo bay.

ASTRO: Would you describe what it's like working with the MMU?

Allen: First of all, the unit is pro-

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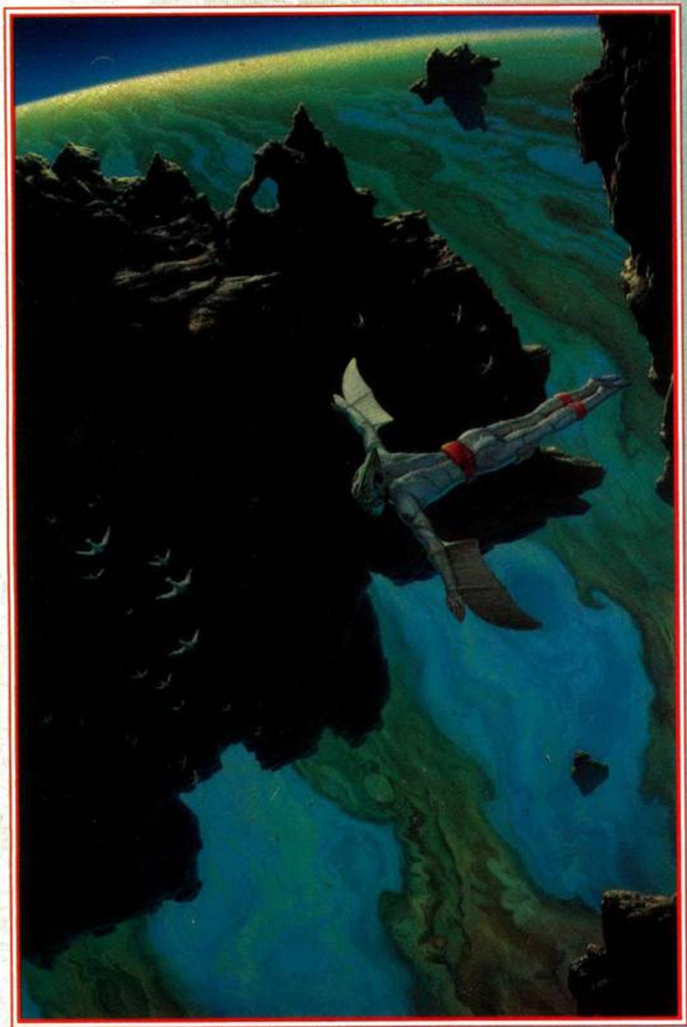

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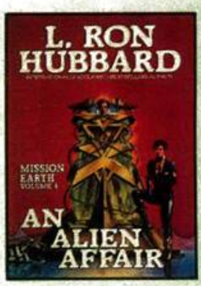

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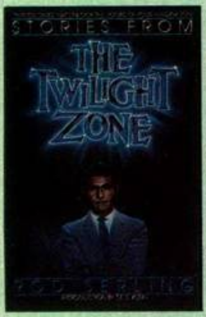

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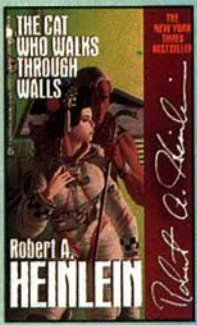
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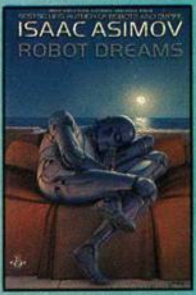

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pelled by compressed nitrogen gas. It has twenty-four thrusters that are operated by tiny relay valves that open and close, releasing high pressure jets of gas through these thrusters into the vacuum of space. Each thruster provides a pound or two of thrust, which is just enough to move the MMU and suited crewman around in a very gentle, well-behaved way.

ASTRO: You control your motion with a pair of hand controllers?

Allen: Right. With the left hand you command the translation, which is your motion back and forth, up and down, and side to side. With the right hand you command the pitch, roll, and yaw. It is a very responsive unit, but you have to concentrate very intently on flying it lest you command too complicated a maneuver. Remember, all motion in space is undamped. That is, each component of velocity you put in must later be taken out.

ASTRO: Getting back to the day of the Palapa retrieval, could you describe the preparations you underwent for the EVA?

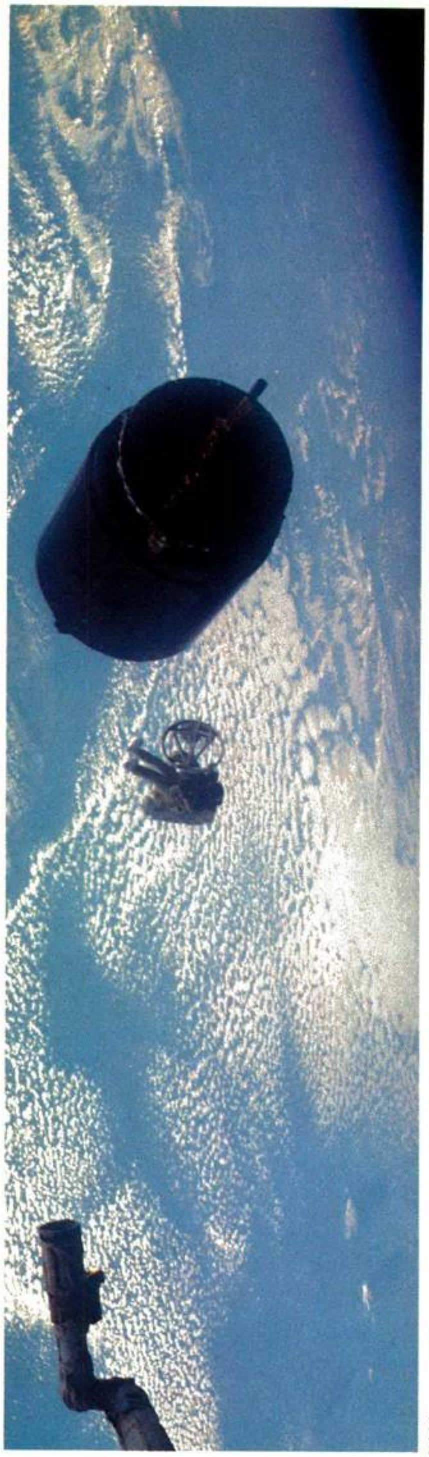
Allen: First of all, before the spacewalk we checked out the suits extensively to make sure they were functioning properly. On the day of the retrieval we knew we would have a pretty full day, especially since the rendezvous procedure had to begin four or five hours before the spacewalk began. Therefore, Rick and Anna were up the first thing that morning doing the final phase of the rendezvous. In the meantime Dale and I were going over our equipment one last time, getting down to those last procedures about three hours before the spacewalk was to begin. This involved putting on biosensors and the liquid-cooled undergarments, outfitting the suit with drinking water and a food stick, and then getting ourselves into the spacesuits and buckling them up.

The suits are mounted on the wall of the airlock. The crewman wriggles into the upper torso of the suit after having donned the lower torso. There is a large ring or flange on each of the two halves that are mated with an O-ring seal between them, thus locking the upper torso and lower torsos together.

Once we were in the suits and had donned the helmets and gloves, we pre-breathed pure oxygen for about forty-five minutes prior to purging our bodies of nitrogen that would otherwise have potentially caused decompression sickness.

ASTRO: Wasn't that pre-breathe time down from the three hours employed on previous Shuttle flights?

Allen: Well, a three-hour pre-breathe is the procedure you follow if you go from the normal atmospheric pressure of 14.7 pounds per square inch down to the 4.3 psi pressure in the suit. We were able to save time on the pre-breathe by lowering the pressure in the Shuttle to 10 psi on the day before the EVA. While we were pre-breathing and the hatch to the Shuttle was still open, David Walker did a final check to verify that we had everything we needed; all the tools were there. Having done that, he floated back out into the middeck and closed the inner hatch to the Shuttle. Now we were all alone in the sealed airlock. We continued down a checklist that was attached to the wall.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ASTRO: Then you went out?

Allen: At that point we began a procedure that lasted about twenty minutes, where after a final check that everything was ready, we began to release the air out of the airlock. Finally, when all of the air was vented, and as Rick went through the last phases of the rendezvous with the satellite, we opened the outer hatch and floated out into the vacuum of space.

ASTRO: What was it like?

Allen: It was wonderful! I went out with my head facing up out of the payload bay. Rick had positioned the Shuttle in such a way that the first thing I saw was the satellite spinning like a toy just as slowly and beautifully as you can imagine. It was so nearby that I felt as if I could reach out and touch it. I felt elated, not only at the view but at the fact that the satellite was spinning without any wobble at all. I knew the minute I saw it that we could get it. There was no doubt in my mind.

ASTRO: You said the plan now called for you to get into the MMU?

Allen: It was mounted on the flight support station inside the payload bay. I snapped into the MMU and unhooked my safety tether. When I pulled my feet out of the foot restraints I was flying untethered in space. I flew the MMU halfway down the payload bay where Dale was waiting to mount the stinger onto the arms of the MMU.

I took a very short flight with the stinger just to make sure I could fly with all this equipment attached. Then we waited for the Sun to rise. Just at dawn Dave gave us the go ahead. I left the payload bay slowly and flew over to get the satellite.

ASTRO: How does it feel to float untethered in space?

Allen: It's a remarkable feeling, a smooth feeling. Of course, you're used to floating and so the floating part was not extraordinary. The untethered part of it was sobering because you're orbiting Earth at a speed of 17,500 miles per hour. You are literally a human satellite. However, you don't feel out of control or apprehensive because of redundancies built into the equipment, and because the MMU is very easy to fly and very responsive.

Getting back to the retrieval. Almost before I knew it I had completed the flyover and I was at the back of the satellite. I had a momentary distraction because of the Sun, but I quickly went into the shadow of the satellite. The light from my helmet shone up into the spent rocket nozzle and I inserted the stinger into the nozzle just as we had practiced so many times on the ground. It went into the nozzle with no problems at all; I don't believe I even hit the sides.

The satellite was spinning, but not very fast, and I pulled a lever on the top of the MMU to open the toggle

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bolts, which assured that I was soft-docked with the satellite.

ASTRO: How could you tell that the toggles were released?

Allen: I could feel them go "clunk," and I could even see inside the rocket nozzle as the toggle fingers opened.

ASTRO: Were you "hard-docked" yet?

Allen: No. To accomplish that I shortened the shaft of the stinger using a steering-wheel-like device. This pulled the satellite to me until the adapter ring of the apogee kick motor was tightly seated against the stinger. The satellite filled my entire vision, and I had the impression that the satellite had come to a stop. It had not; instead, I had begun to turn with the satellite. Turning was not alarming, and, in fact, I could not even sense it.

At that point I stabilized us both — the satellite and myself — by pressing a button on the MMU. That caused gyroscopes in the MMU to engage in such a way that they fired the nitrogen thrusters and stopped the satellite from tumbling. Then Anna gave me directions to orient the satellite so that she was able to reach it with the robot arm. She latched onto the grapple fixture and captured the satellite and me.

So far everything was going exactly according to plan. The robot arm was holding onto the grapple fixture on the stinger, I was still attached to the stinger, and the stinger was attached to the satellite.

Dale began to fasten the A-frame. I could feel him jostling the satellite around a little bit. He seemed to be pushing very hard. Then he said, "Joe, one of the brackets that holds the A-frame is not fitting. There is something in the way." He unwrapped some thermal protection material and reported in a somber voice that there was an unexpected, large electronic structure protruding into exactly the wrong place. It was preventing the A-frame bracket from clamping properly.

Our hearts sank. Try as he might, it just wouldn't fit. We decided that we were going to have to go to the backup plan. Had the adapter not worked, there was no workaround; the procedure would simply have been to throw the satellite away.

However, in the case of the A-frame there was a back-up plan — a crucial plan B! The essence of plan B was, if the A-frame did not work in holding the satellite, we would substitute a person for the A-frame. That person would have to hold the satellite at the top. That person was me.

ASTRO: It sounds very difficult.

Allen: It was. And not just for me holding the satellite, but also for Dale who would have to put on the adapter single-handedly. In any event, Dale mounted a portable foot restraint on the pallet near one of the longerons of the Shuttle. Then I pulled myself away from the stinger, stowed the MMU, and got into the foot restraint.

Ever so gently, Anna handed the top end of the satellite to me. I grabbed onto it and she released the robot arm's hold on the grapple fixture. To my surprise and enormous relief, I found that I was able to handle the satellite. It was not even that difficult to hold on to. Thank goodness for Newton's physics!

The satellite weighed nothing at all, and yet it was quite massive, thus quite stable, even though Dale was pushing and struggling at the other end. He single-handedly fastened the adapter and torqued down nine clamps, which collectively brought to bear 70,000 pounds of force holding the adapter onto the satellite.

ASTRO: How long had you been out?

Allen: By that time we had been EVA for about four hours. We were starting to feel genuine fatigue, but our task was not finished. I let go of the satellite completely while Dale held it and the adapter. That whole combination would have weighed nearly one ton on the ground, but he was able to control it long enough for me to leave my position and move down closer to the pallet where the satellite would be berthed. Dale guided the satellite and adapter over to me and I held it as he also repositioned himself down by the pallet.

The two of us were able to lower the satellite into the devices on the pallet that held the three trunnions of the adapter. Rick and Dave threw switches inside Discovery that automatically caused latches to clamp onto the trunnions, holding the satellite into place. We had done it. The errant satellite had been captured alive.

ASTRO: How did you feel at that point?

Allen: Wonderful, just wonderful! Even though we had run up against a tough problem with the A-frame, we had been able to manually get around it by literally hand-wrestling the satellite into submission, using a procedure we had discussed but never practiced. We were elated.

ASTRO: How different was the second retrieval?

Allen: The second one was complicated by the fact that Palapa was already berthed in the payload bay, taking up half of our storage volume. This meant that if we had the same A-frame problem with Westar that we had with Palapa, we would no longer have the luxury of an empty payload bay in which to maneuver. We also had the added risk of bumping the two satellites together.

We decided to develop still another backup plan, eliminating the A-frame altogether. It called for me to be placed on the manipulator foot restraint at the end of the robot arm. Dale would make the flyover to Westar, stabilize it, and hand the top of the satellite over to me. I would hold onto it by the omni antenna while Dale single-handedly attached the adapter. Then, with me affixed to the arm and holding the satellite, the robot arm would be maneuvered so that I could thread the three trunnions into their holding devices. Using the new procedure, the second retrieval took only four hours.

ASTRO: How do you think your EVA compares to those of the Gemini, Apollo, and Skylab programs?

Allen: Our EVA was just another step in an evolutionary process that began with Ed White's historic spacewalk in 1965. The first spacewalks during the Gemini programs were exploratory and somewhat tentative in nature. Those during Apollo were elaborate EVA's that took place on the Moon. Those of the Skylab era involved on-orbit repairs to the Skylab and then a number of EVAs to exchange large film canisters outside that spacecraft. Each of those EVAs taught us something important. By building upon what we learned in these earlier missions, we were able to pull this mission off.

Just as we were taught by those who went before us, we in turn can teach some good lessons to those that will follow. One of the things our flight proved was that something very large and weighing on the order of one or two tons on the ground is very well behaved and easy to handle in zero-gravity.

ASTRO: What are the implications of this to the construction of the Space Station?

Allen: Well, there are many. First of all, there is no reason why a space-worker cannot construct something as large as a building in orbit or move entire modules around and bolt them together. There is no reason that it cannot be done, and we are very confident when we say that.

We can build a series of very fancy modules that will unfold automatically and construct themselves in orbit, or we can build a much cheaper version and have laborers like Allen and Gardner bolt it together.

Seriously, our flight clearly demonstrated the human flexibility and versatility. The satellites were back on the ground and back at the Hughes Aircraft plant being readied for relaunch into space less than ten months after they were lost in space.

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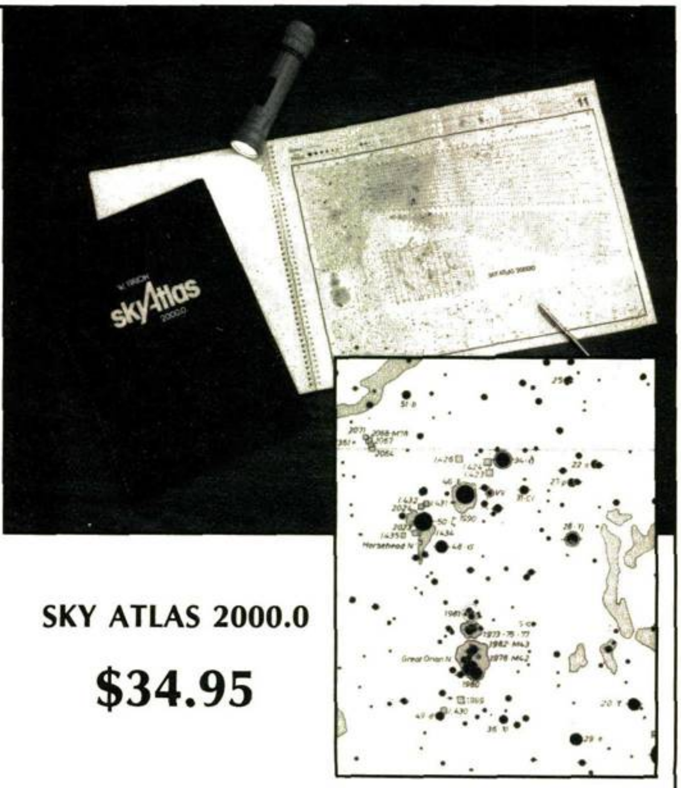

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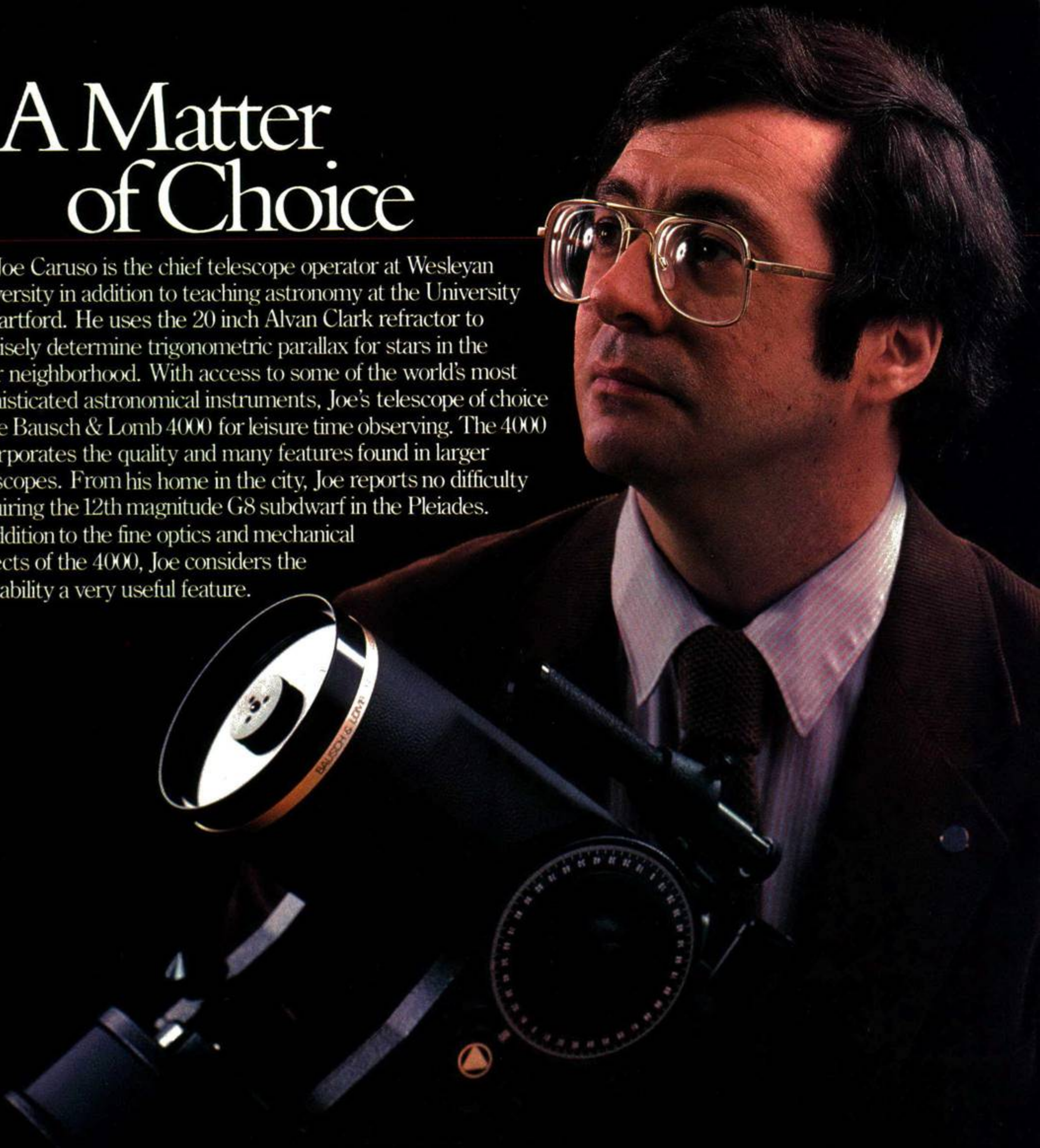
A Matter of Choice

Joe Caruso is the chief telescope operator at Wesleyan University in addition to teaching astronomy at the University of Hartford. He uses the 20 inch Alvan Clark refractor to precisely determine trigonometric parallax for stars in the solar neighborhood. With access to some of the world's most sophisticated astronomical instruments, Joe's telescope of choice is the Bausch & Lomb 4000 for leisure time observing. The 4000 incorporates the quality and many features found in larger telescopes. From his home in the city, Joe reports no difficulty acquiring the 12th magnitude G8 subdwarf in the Pleiades. In addition to the fine optics and mechanical aspects of the 4000, Joe considers the portability a very useful feature.



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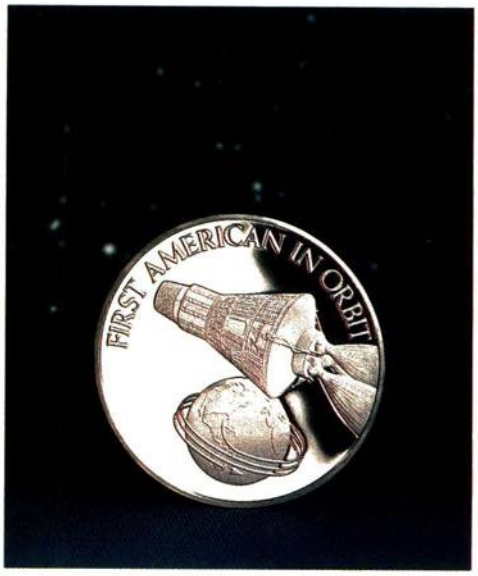
FIRST AMERICAN IN SPACE
Alan Shepard becomes the first American in space when his Mercury 3 spacecraft blasts off from Cape Canaveral in 1961.



FIRST AMERICAN IN ORBIT
John Glenn circles the earth three times in his Mercury 6 capsule.

FIRST AMERICAN SPACE WALK

FIRST AMERICAN SPACE WALK
Astronaut Ed White leaves Gemini 4 to walk in space for 21 minutes.

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Thus it is both fitting and proper that The National Space Institute in Washington, D.C., will issue a special commemorative tribute to mark this historic occasion.

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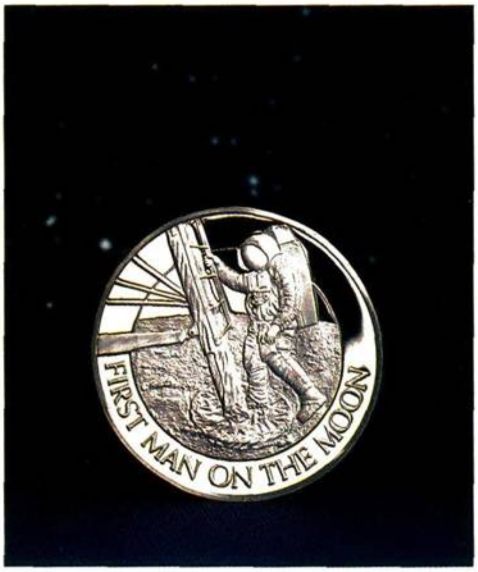
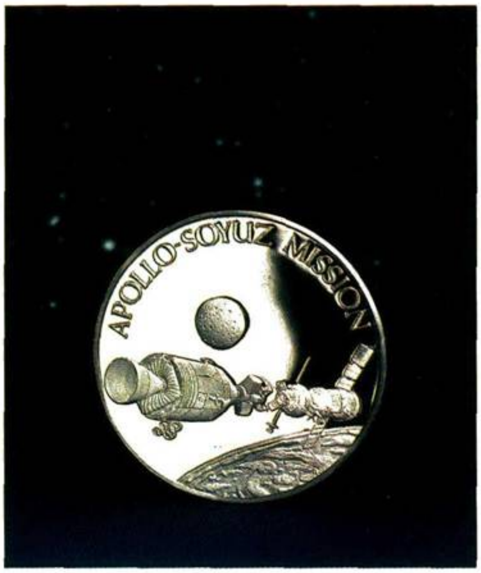
Gemini 8 spacecraft links up successfully with an Agena target rocket which had been placed in orbit earlier.



FIRST MAN ON THE MOON
Neil Armstrong takes his "one small step for man" as he walks on the surface of the moon.



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ASTRONOMY
In Focus

No More Halley Photos!

Sir / After reading your September issue, *which came in July*, we beg you on bended knee: Please, no more Comet Halley pictures! We've had enough!

Dennis Koenig
Clifton, NJ

A Born-Again Astronomer

Sir / Although I am very fond of astronomy now, I can remember a time when my enthusiasm waned after I first became interested in astronomy several years ago. I used to take a kitchen chair outside and sit on the front lawn for hours staring at the stars. But after awhile I felt that something was missing, that there must be more to backyard observing.

It gradually became much easier to spend all day and night watching television than to go to the trouble of gathering everything together, going out, setting up, and attempting to focus my stubby 50mm telescope on an object that looked blurry anyway.

It was only when I subscribed to ASTRONOMY that I began to become re-interested in the universe. It started when I read "Target: Uranus!" in the September 1985 issue. But the magic really hit me when I saw the pictures in "How to Revive Dull Astrophotos" in the January 1986 issue.

Since then I have attended my first regional stargaze in Mississippi. Your magazine prevented me from becoming a human picture tube. I can't tell you how grateful I am!

Steve Sutton
Springfield, GA

What an Amateur Can Do

Sir / I am writing to report my observation of a feature on Jupiter that I have never seen before and that was not evident during the 1985 Jupiter season. I made four observations of this feature using a 6-inch f/8 Newtonian reflector and 4mm, 9mm, and 12mm eyepieces.

While observing Jupiter on June 22, 1986, my attention was instantly drawn to an obvious spot on the south edge of the North Equatorial Belt. I knew that it wasn't the Great Red Spot, and a quick check of ASTRONOMY's Jovian satellite chart showed that all four of the Galilean moons were either at elongation or in eclipse. At 08:45 UT (4:45 a.m. EDT), the spot was west of the Jovian meridian, almost half way from the meridian toward the western limb. It looked very much like a shadow of Ganymede — distinct, dark, and about 2 arcseconds in diameter. But it had the reddish-brown hue so familiar in Jovian belts and appeared to be connected to the North Equatorial Belt, penetrating well into the Equatorial Zone.

Based on Jupiter's rotation period, I scheduled my next observing session for June 24. That morning I was surprised to see not one spot but two connected by a reddish-brown arch. This "loop" measured 12 arcseconds by 2 arcseconds, representing almost 27,000 miles of Jovian longitude. The trailing eastern spot was the darker of the two features. At almost precisely 9h UT (5 a.m. EDT), the eastern spot transited Jupiter's central meridian.

Based on these observations, I knew the next transit on June 26 would be nearly impossible to observe, as the loop would not transit until about 10h UT (6 a.m.), forty minutes after sunrise. At 9h UT, I was able to detect the leading (western) spot and about half of the loop extending back toward the eastern limb.

During my fourth observation on June 29 I was able to confirm loop transit at 06:50 UT (2:50 a.m. EDT). Related to the June 26 observation,

ANNOUNCEMENT OF OPPORTUNITY

The Hubble Space Telescope Amateur Astronomers Working Group is pleased to announce a program for amateur astronomers to apply for observing time on the Hubble Space Telescope (HST), the most advanced telescope ever built. A limited amount of time is being reserved especially for amateur astronomers on HST by NASA and the Space Telescope Science Institute. Your response could open a new era in amateur astronomy.

This program is open to readers of ASTRONOMY who are U.S. citizens, who are not professional astronomers, and who have specific projects of scientific or educational value requiring the use of the unique capabilities of HST. With its high sensitivity, extended wavelength range, and high resolution, Space Telescope offers many exciting opportunities for astronomical study. Observing time on Space Telescope is so highly sought after that its uses are limited to studies impossible from the ground.

Readers interested in receiving instructions for making preliminary proposals should send $1.00 (to cover the cost of materials, postage, and handling) to:

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The deadline for completed applications is March 31, 1987. Please make checks payable to the AAVSO.

this gave a surface rotation period of 9 hours and 51 minutes, which fits very well with the period given in textbooks. The loop also appeared slightly thinner and longer than on June 26, with a total length of 14 arcseconds, about one-third of the Jovian disk!

David M. Lindemann
Poughkeepsie, NY

A sketch of Jupiter made by David Lindemann shows a cigar-shaped feature along the southern edge of the North Equatorial Belt. (South is at top.)

— We forwarded these and other subsequent observations made by Mr. Lindemann to the Association of Lunar and Planetary Observers (ALPO). In a reply to Mr. Lindemann, Philip Budine, Jupiter recorder for ALPO, wrote, "Your observations were well executed and accurate. They proved most valuable to the ALPO Jupiter Section. . . . Your feature is a dark, long-lived (since 1985) blue festoon. It was first seen on May 29, 1985. It is called OL-14 (Olivarez Blue Feature, number 14). You were the first to observe its darkening in 1986! . . . Thanks again for an outstanding piece of observing. Your active effort is most appreciated."

Aside from the importance of Mr. Lindemann's observations to planetary astronomy, it is noteworthy that with average equipment he did something above average. He made detailed sketches, took plenty of notes, and had his observations confirmed by others — all important factors in making a scientific report.

Valuable contributions to astronomy can still be made using nothing more than a small telescope, a keen eye, and prudent judgement about what is being observed.

Old Comet, New Interest

Sir / Now that Halley has come and gone, I thought you might be interested to know what a very amateur astronomer gained from its appearance.

I have been waiting twenty years (since I was 12) to see the famous comet, but I had no idea of the other wonders that can be seen with nothing more than binoculars. During the past few months Halleymania prompted me to get a cosmic education. It doesn't matter to me if this was one of Halley's poorer showings. I made over twenty sightings with 7x50 binoculars and feel as though I saw something truly heavenly.

My best view was on March 14, about an hour and a half before dawn, when Halley was an easy naked-eye object and sported an equally visible 5°-long tail.

This was quite different from anything I had ever seen before. After I had gazed in awe at the well-defined tail, I casually swept my binoculars to the southeast and was dumbfounded to see what I now know to be M-8, M-20, M-24, M-18, and M-17. I was hooked. I now own an 8-inch Dobsonian reflector and will be forever grateful to Halley's Comet even if this was a poor showing.

There has always been an astronomer inside me. Comet Halley has reminded me of this. Now my five-year-old son joins me in exploring clusters, galaxies, nebulae, and the planets.

Tom Johnston
Boulder, CO

Oops!

The photo on page 54 of the July 1986 issue was taken by Rick Dyson at the Amundsen-Scott South Pole Station.

In the September 1986 issue ("Forum," p. 30), Phillip Dombrowski's actual estimate of the angular diameter of the coma of Halley's Comet was one-half of a degree.

In the January 1986 issue an article appeared under the byline of Bill Katz. The edited story suggests that the object depicted on the photo published with the story may be a film flaw. Mr. Katz believes that the photo represents a genuine flash event. He has complained that this and some other passages in the story distort his views and the progress of his research at the time.

Behind the Scenes

What's Next in Space?

The Challenger explosion profoundly altered the American space program. Today, despite President Reagan's announcement to build a fourth orbiter (presumably in support of the Space Station), the direction and goals of the U.S. space program are still in disarray.

It is still not clear what will happen to astronomical and planetary missions, or whether their funding will be dropped or deferred since they can't be launched anyway. It is still not clear whether private companies, even if they are heavily subsidized by federal funds, will be able to compete with Europe's Ariane launchers, or whether they will be able to do the job any better or cheaper than NASA did before it got involved with the Shuttle. It is still not clear what the future role of "crewed" spaceflight will be. With scientific satellites launched by expendable boosters and communications satellites by "privatized" launch vehicles, what's left for the Shuttle to do?

One thing is clear: NASA's image is tarnished. That may be just as well, however, because the image has long been unrealistically bright and shiny. Mass media coverage was occasionally harsh, but by the standards of criticism we expect for other branches of government, our national space agency was treated gently by the press.

The slow-to-come revelation that NASA has no convincing evidence that the astronauts died immediately — or even soon — after the breakup of Challenger was unfortunate. Whatever the truth, the timing of the announcement made it look bad, as if NASA wanted to hide it.

However, I wonder if we are right in wishing the astronauts an instant extinction, free of any awareness of their impending death. Is it right for someone who knowingly risks his or her life to participate in this century's greatest adventure to be snuffed out, unaware of what has happened? If not, is the awareness worth the agony? There are no answers to these questions and no comfort in thinking about them.

But there is some comfort in thinking about what kind of men and women fly the Shuttle. They have to be different, and what sets them apart is the willingness to ride the big rockets into space, knowing what can happen, and to accept the terrible consequences when technology fails.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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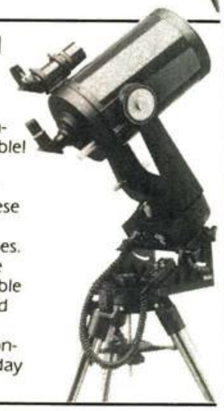

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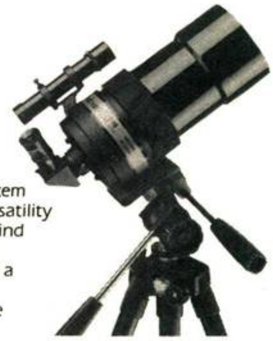

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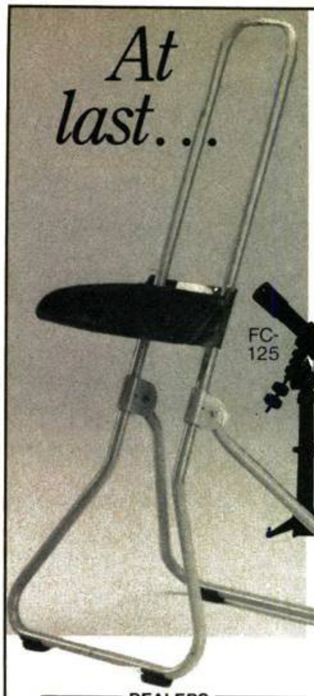

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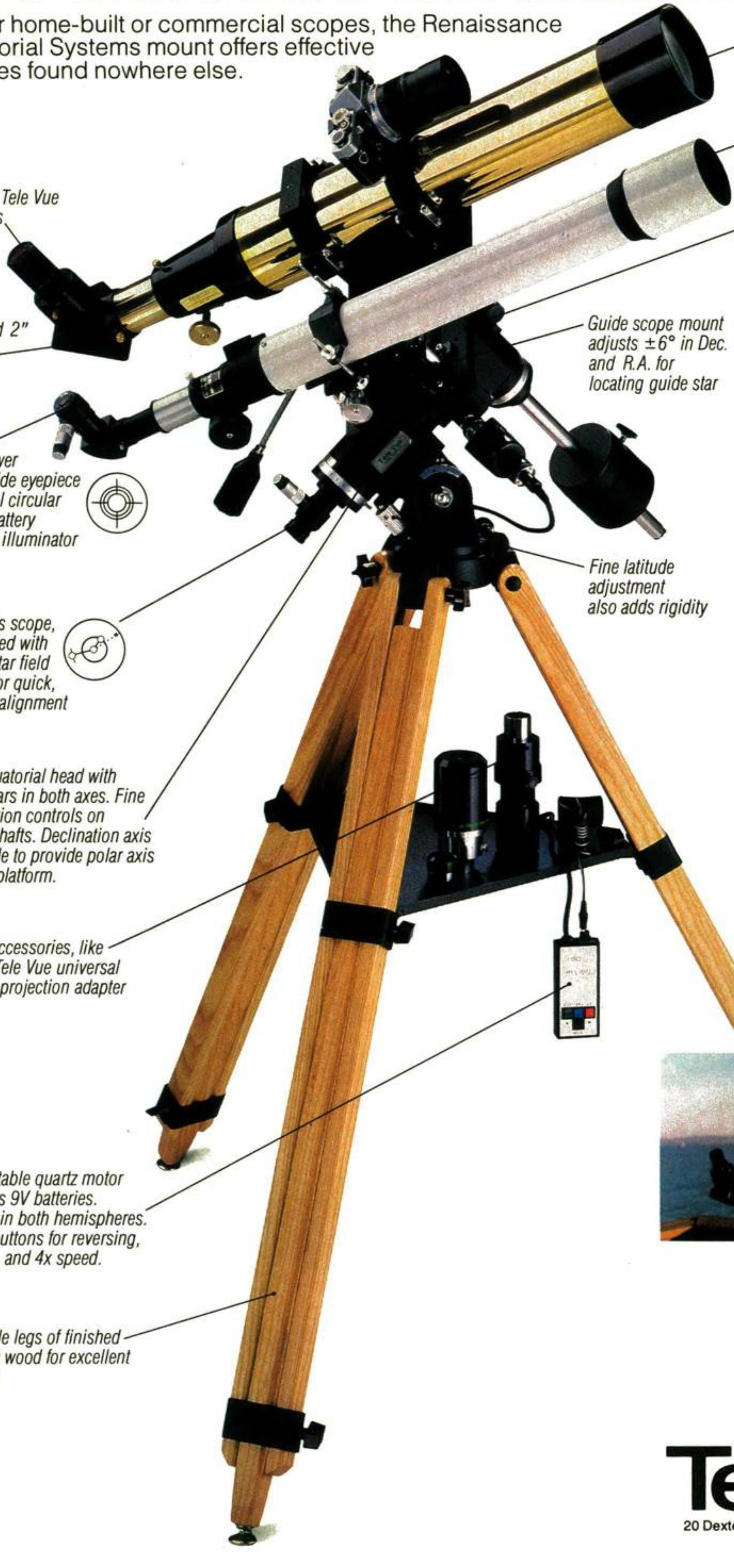

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Three Faces of Halley

Three Faces of Halley

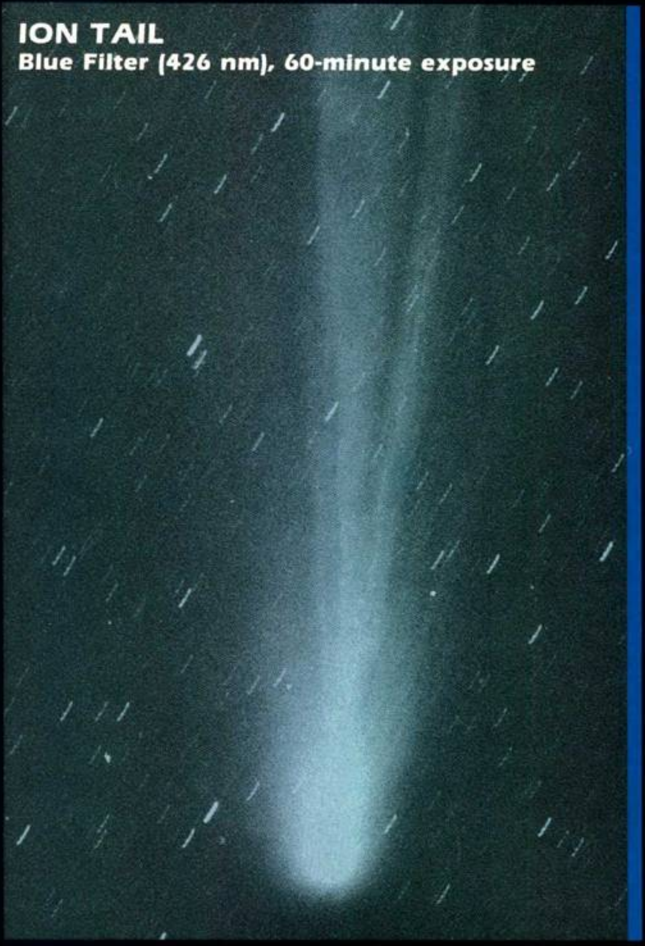
Three Faces of Halley

On the morning of March 16, 1986, from a remote mountaintop observatory at La Silla, Chile, West German astronomers from the Bochum University Halley Observing Group exposed three photographs of Comet Halley through color filters using a 190mm aperture f/4 flat-field Schmidt camera. The filters were carefully chosen to emphasize different aspects of the comet.

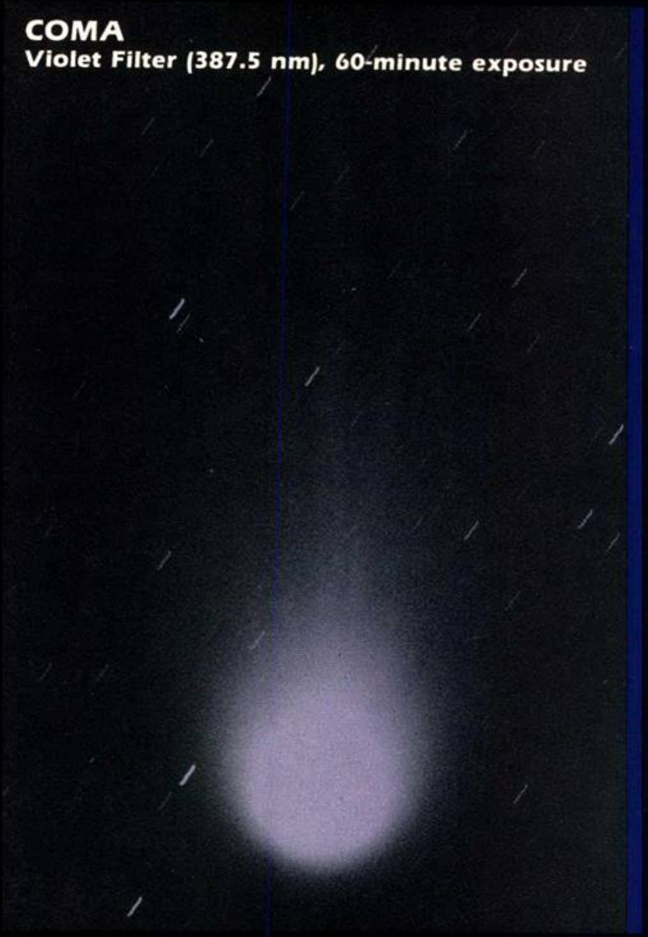
A yellow filter transmitted sunlight reflecting from the dust tail, a blue filter isolated the glow of carbon monoxide ions (CO^+) in the ion tail, and a violet filter passed the light of fluorescing molecules of cyanogen gas (CN) in the coma. The astronomers used hypersensitized 103a-F film for the exposures.

To make the color image on the opposite page, the three resulting black-and-white images were superimposed as subtractive primary colors. In the composite, the coma shows as a blue halo, the ion tail glows greenish yellow, and the dust tail appears orange.

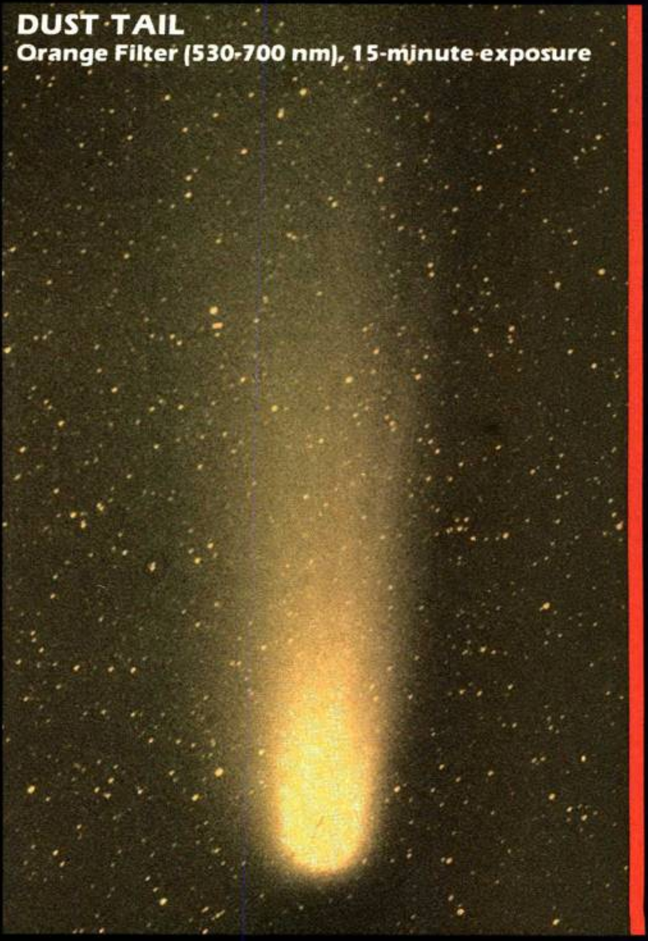
Original photos courtesy P. Koczet and R. Schultz of the Halley Observing Group, Astronomisches Institüt, Ruhr-Üniversitat Bochum. Color composite by National Colorite Corp.



ION TAIL
Blue Filter (426 nm), 60-minute exposure



COMA
Violet Filter (387.5 nm), 60-minute exposure



DUST TAIL
Orange Filter (530-700 nm), 15-minute exposure

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ASTRONOMY
Reviews

300mm f/5.6 Minitel-S mirror telephoto lens
Lens, T-ring, and case, $119.95
Spiratone (1986)

The new 300mm lens from Spiratone surprised me. Because of its modest price I expected average performance, but the lens turned out to be one of the best I've ever used. Star images are crisp all the way to the edge of the field, and the corners are almost as bright as the center. Under a dark sky, exposures with hypered Tech Pan reach the sky fog limit in 15 to 30 minutes.

Best of all, the Minitel-S is no heavier than some 50mm lenses, so piggybacking with it won't overload your telescope. The lens is about 3 inches long and 3 inches in diameter. It protrudes somewhat below the level of the bottom of the camera, so the camera can't be mounted in the middle of a large, flat plate. However, both the Celestron 8 and Meade 2080 piggyback adapters work fine.

The Minitel's star images are crisp because most of the work is done by mirrors, not lenses, which greatly reduces chromatic aberration. The optical system is a modified Maksutov-Cassegrain optimized for a wide, flat field rather than central sharpness. The front element is double convex rather than the usual meniscus, and the main mirror is actually a glass lens element aluminized on the back. Before exiting, the light passes through a negative element that expands and flattens the image. All surfaces are spherical.

The Minitel-S mounts on any 35mm SLR camera by means of a T-ring, which is included in the price. Like all T-mount lenses it should be focused on the stars, not just set on the infinity mark. It accepts 72mm filters on the front and 30.5mm filters on the rear.

Besides starfield photography, the Minitel-S is useful for eclipses, especially total solar eclipses, because it has a wide field and moderate f/ratio. On the other hand, it is not sharp enough for detailed photography of the Moon's surface; even on fine-grain film, such pictures show only the largest craters. *Michael A. Covington.*

The Lagoon and Trifid nebulae in Sagittarius, photographed with Spiratone's 300mm f/5.6 Minitel-S lens. This 8-minute exposure on hypered Tech Pan film covers less than half of the original frame. Photo by Michael A. Covington.

The Star Guide
Steven L. Beyer
404 pages, cloth, $22.95
Little, Brown, & Co. (1986)

Many books have been produced to help beginning stargazers familiarize themselves with the often intimidating field of amateur astronomy. There are several good works on the subject, but the great majority are either condescendingly simple or poorly written, which leaves novices groping to understand the basics. On the other hand, many well-written books about astronomy are simply way over the heads of most beginners. Fortunately, Steven L. Beyer has found the middle ground in his book.

The Star Guide takes the best points of many introductory books and creates a well thought out, non-complex approach to presenting concepts the beginner should learn in order to understand the basic workings of the nighttime sky. The author's explanations are clearly written. The book also contains a valuable glossary of commonly-used astronomical terms.

The book covers 105 of the sky's brightest stars (called "featured stars") and shows the locations of each on a "sky screen" for the date that star is visible in the eastern sky at 9 p.m. local time. This finder chart shows the star, the horizon, and some bright stars nearby to make identification easy.

The charts are not cluttered with labels and faint stars so that the patterns of bright stars are not interfered with. Below each chart is a table listing the star's name, designation, right ascension and declination, transit date, distance, and "Star Time Reference" number (see below). Other objects of interest such as galaxies, nebulae, and star clusters are covered in the accompanying text.

The "Star Time Reference" is a unique

system providing each star with a number between 0 and 1440. The system is based on the number of minutes in twenty-four hours, and indicates the separation in minutes between arrivals of various stars over the eastern horizon. By adding or subtracting the numbers you can determine the length of time between two featured stars coming into view, transiting, or setting. This allows you to plan a night's viewing.

I've seen too many beginning astronomy guides that fail to explain themselves adequately. Beyer devotes much of the text to explaining how to use the book, a strong point for rank beginners. The book also briefly discusses the history of astronomy and includes data tables with useful information about a variety of astronomical topics.

The Star Guide is a good investment for the library of a beginning stargazer and will certainly become one of the most dog-eared books in such a library. *Robert A. Garfinkle.*

Star Seeker
Software for the Commodore 64 computer
Disk and instruction booklet
Mirrorsoft (1985)

This software package for the Commodore 64 is a British import that displays data on constellations, planets, and phases of the Moon. Unfortunately, this potentially useful tool has numerous faults, beginning with the poorly written instruction manual.

The package has a "boot" program for choosing and loading your choice of the solar or stellar programs. Although the disk label instructs you to load the boot program, the manual doesn't mention it at all. But you can still follow the instructions in the manual and load the programs by name as they appear in the directory using the keyboard. From here, however, things go downhill.

The disk is copy protected, which caused my disk drive to chatter, as do many copy-protected disks. Typing in an override code thwarts this problem.

The star and planetary maps are based on Greenwich Mean Time rather than local time or right ascension. A chart of longitudes, latitudes, and time corrections is given for several major cities, but there are no instructions on what to do with the time corrections. For example, the book shows −6 hours for a Chicago-based observer. A beginner would probably subtract six hours from GMT and get a very strange star map. You actually have to *add* six hours to get a correct display for Chicago.

Once you get the thing going, at least it works. Suppose you have the star map program loaded and local time under control and you want to see what the western sky looks like. You hit the "W" key and the map gets plotted, one star at a time, in about one minute. After this a menu appears at the bottom of the map giving you choices of what to do.

Your choices include choosing a new cardinal direction, a narrower angle of view, a new time or location, continuous time progression, star data, constellation lines, or printing a hard copy of a map. If you select continuous time progression, the map is processed one hour at a time. The screen goes blank for about one minute while the new map is calculated, making it difficult to follow the star movement. The other choices are equally slow.

If you select constellation lines, the map goes blank for a few seconds, replots the stars, and then starts adding the lines one at a time. A glitch in this function is that if one of the constellation's stars is off the screen, none of the lines for that group is plotted.

You can print hard copies of any star map — with or without constellation lines — but you may not want to. The program prints one row of dots at a time while laboriously oscillating the printhead back and forth. I let my Epson printer run for about half a line and then aborted the printout in self defense.

The solar system program is similar to the star program, but there is no way to show the planets on a starfield. You only get data on their positions, brightnesses, etc.

The Moon phase option is a real turkey. After you enter the date and time, the Moon's age and position, along with a picture of its disk, is displayed on the screen. It's only a featureless crescent or disk, but it takes eight minutes to plot line-by-line.

My suggestion to Commodore users: skip this program and get Commodore's *Sky Travel* instead. *James Bailey.*

Science Confronts The Paranormal
Kendrick Frazier, ed.
367 pages, paper, $15.95
Prometheus Books (1986)

This is a collection of critical essays and investigative reports on nearly every area of the paranormal — from ESP and UFOs to palmistry and creationism. The authors adhere to strict reasoning and scientific procedure in analyzing "verified" paranormal events, which results in a sobering appraisal of fringe science claims.

Sightseeing
Barbara Hitchcock, ed.
105 pages, cloth, $24.95
Alfred A. Knopf (1985)

Sightseeing is a collection of eighty-four color photographs from the NASA archives that includes shots of Earth from space, Shuttle activities, lunar geography, and spacewalking.

Frontiers of Modern Physics
Tony Rothman, *et. al.*
197 pages, paper, $6.95
Dover Publications (1985)

Frontiers is primarily composed of a series of reprinted articles, some originally published in the late 1970s and early 1980s in *Analog* and *Isaac Asimov's Science Fiction Magazine*. The authors, nearly all of whom are either staff members or visitors at the University of Texas Center for Relativity Theory in Austin, attempt to bridge the gap between what physicists are really saying about current theories and the misconceptions harbored by lay readers. Articles include, "On Cosmology," "Demythologizing the Black Hole," "The New Neutrinos," and "Extraterrestrial Intelligent Beings Do Not Exist."

1986 Yearbook of Astronomy
Patrick Moore, ed.
231 pages, cloth, $15.95
W. W. Norton (1986)

The *1986 Yearbook of Astronomy* is an observer's handbook listing monthly astronomical phenomena, constellation charts, and notes on Moon phases, occultations, and eclipses. The back pages contain articles by various authors on such topics as observing the Sun in Hα light, photoelectric photometry for amateur observers, and spiral galaxies.

Invitation to Astronomy
Simon and Jacqueline Mitton
210 pages, paper, $8.95
Basil Blackwell (1986)

This is an overview of astronomy for fairly advanced readers. It opens with a cosmological perspective, followed by chapters on the night sky and historical astronomy. Subsequent chapters cover current topics, including stellar evolution, telescope technology in professional observatories, galaxies, black holes, and the nature of the universe. There are also chapters on astronomy as a profession and the future of astronomy.

The Anthropic Cosmological Principle
John D. Barrow and Frank J. Tipler
706 pages, cloth, $29.95
Oxford University Press (1986)

This expansive work details the past and present cosmological findings supporting the anthropic principle, the concept that the evolution of the universe is adapted to the presence of life. In addition to physical and cosmological designs of the universe, the authors address modern as well as past teleologies and their relation to the anthropic principle.

Kodak Hobby-Pac™ Color Slide Kit
Chemicals for processing color slide film, $13
Eastman Kodak Co. (1986)

This processing kit, available at most photo supply stores, contains chemicals for processing six 36-exposure rolls of Ektachrome, Fujichrome, or other similar color slide films. Unlike standard E-6 processing kits, this one uses only four chemicals and works at any temperature between 70° and 100° F. And it is priced low enough so that processing your own slides has finally become cheaper than taking them to the corner drugstore.

The four chemicals — a first and second developer, blix, and stabilizer — are supplied as liquid concentrates, most of them in foil packets. Because there are no powders to dissolve, making the solutions takes only a few minutes. Each packet makes 500 milliliters of working-strength solution — enough for a two-reel developing tank.

The kit gives best results at the traditional E-6 temperature of 100°F. At lower temperatures the developing times become longer and color balance shifts slightly toward yellow. If color balance isn't critical you can get acceptable results working at room temperature with no temperature control.

With this kit you can see your slides half an hour after you take the pictures (while there's still time to try it again!). You can develop hypersensitized film immediately, before it has time to fog. And you can alter the film speed by varying the first developing time.

The instructions supplied with the kit tell how to "push" film by as much as three stops, increasing its effective speed by a factor of eight. You can equally well "pull" film to reduce its speed, yielding slightly finer grain and lower contrast.

With processing your own slides you get to mount the slides yourself; no one else will scratch them or cut them incorrectly. You don't need an enlarger, nor do you face the time-consuming task of making prints after developing each roll. With color slides, half an hour in the darkroom gives you the finished product.
Michael A. Covington.

Meditations At 10,000 Feet
James Trefil
236 pages, cloth, $16.95
Charles Scribner's Sons (1986)

Meditations combines a climb up a mountain with a way to look at the world as an interconnected web of events. Trefil links natural phenomena to larger scientific theories and issues of global concern. How does whitewater in a mountain stream relate to the fluctuations in insect populations? Why should the existence of two types of rocks at Devils Tower, Wyoming, influence the way physicists look at the world?

"If your goal is to understand the universe," writes Trefil, "a hike through the mountains is as good a place to start as a day at a synchrotron, and a mountain stream can tell you as much as a telescope."

A Brief View of Astronomy
Jay M. Pasachoff
285 pages, paper, no price given
Saunders (1986)

This is an introductory college textbook covering all aspects of astronomy from the solar system to cosmology.

Pioneering Space
James E. and Alcesits R. Oberg
298 pages, cloth, $16.95
McGraw-Hill (1986)

Pioneering Space approaches past and future U.S. and Soviet space exploration from a human perspective, offering hypothetical scenarios for future space missions. The authors also discuss how mankind is beginning to change as a species because of spaceflight. A look at space travel and technology in the distant future is also offered.

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Photography in Astronomy

Advanced Astrophotography

by Mace Hooley

We've all seen the outstanding photographs made by the big observatories and drooled over their rich colors, intricate detail, and remarkable tonal range. Perhaps we've been brave enough to compare them to our own astrophotos. After critically examining them, we resign ourselves to be content with the results we're getting. After all, professionals do have larger telescopes, better skies, 8x10 or larger film, and computer-controlled tracking. But still, we want our astrophotos to be great!

So what can you do? Move to Australia for darker skies? Build bigger telescopes and invest small fortunes in sophisticated computerized guiders? Perhaps. But my advice is to use what you have. The problem isn't altogether in the hardware, it's also a matter of your film processing techniques.

Aesthetically, the big difference between amateur photos and those made at professional observatories is that ours are flat and lifeless. Sharpness isn't a problem for us, but our negatives lie there, colorless, murky, and uninteresting. How do we turn up the color?

There are several ways to simultaneously boost color and contrast in your astrophotos. The most effective methods are tricolor astrophotography, composite photography, and a variety of after-the-exposure "contrast enhancement" techniques using an existing image. Each of these methods has its own strengths and drawbacks.

Bear in mind that these techniques are not meant to be carried out by those just learning astrophotography. To appreciate these more complex methods, it is essential that the beginner first understand how such variables as film speed, exposure, and aperture relate to one another. In fact, you may find that you don't want or need to go any further than that. (See "Fundamentals of Astrophotography," April 1986.) Let's look at each method in turn to see how they can liven up your astrophotos.

Tricolor Astrophotography

Tricolor astrophotography involves recording the light from a subject in its three component colors — red, blue, and green — and then reconstructing each color later in the slide copier or darkroom. This allows you to manipulate the different colors separately, in effect determining how much of each color will be in the final scene by how long you make each color exposure. But perhaps the greatest advantage of tricolor photography is that you can choose a contrasty black-and-white film for the original exposures, which produces snappier original films to work with.

Kodak's Technical Pan 2415 film is the ideal tricolor photography medium. It has high contrast and very fine grain. Because of its spectral sensitivity, Tech Pan works best for the red and green exposures; IIIaJ (one of Kodak's spectroscopic-series films) works best for the blue exposure, despite its coarser grain. If you want to use only 2415 film, it does fairly well for blue exposures, too. (For more about black-and-white films see "Astrophotography with Tech Pan 2415 Film," July 1986.)

Let's say you want to capture the subtle filamentary nebulosity in your favorite Milky Way starfield via tricolor photography. First, you would make three separate exposures of the same region, one through each of the red, green, and blue filters. The best filters for the job are red Wratten 29, blue 47, and green 61. Your exposures at f/2 (using Tech Pan) should be: red, 25 minutes; blue, 120 minutes; and green, 90 minutes. At f/4, these exposures increase by a factor of 4. Using weaker filters (Wratten numbers 25, 44, and 58, respectively) will reduce the necessary exposure time but will also lessen the color contrast.

After you have developed the black-and-white negatives, mount them in 2x2 slide mounts and convert them to black-and-white positives using a slide copier and Tech Pan film, like you would if you just wanted black-and-white slides. At this point you will have three black-and-white pictures of the Milky Way, one in red light, one in green light, and one in blue light.

To convert these three black-and-white slides to a color image, load your slide-copy camera with Fujichrome 100, select a light source balanced for daylight, such as a Wratten 80A filter with a tungsten light source, set the camera's light meter to ISO 200 (Tech Pan's tungsten speed), and insert the red-light slide into the copier. Place the red filter that you used to make the original exposure between the light source and slide, and copy the slide onto the Fuji film, being sure to bracket a few stops around the camera-recommended exposure. This will produce the cyan negative.

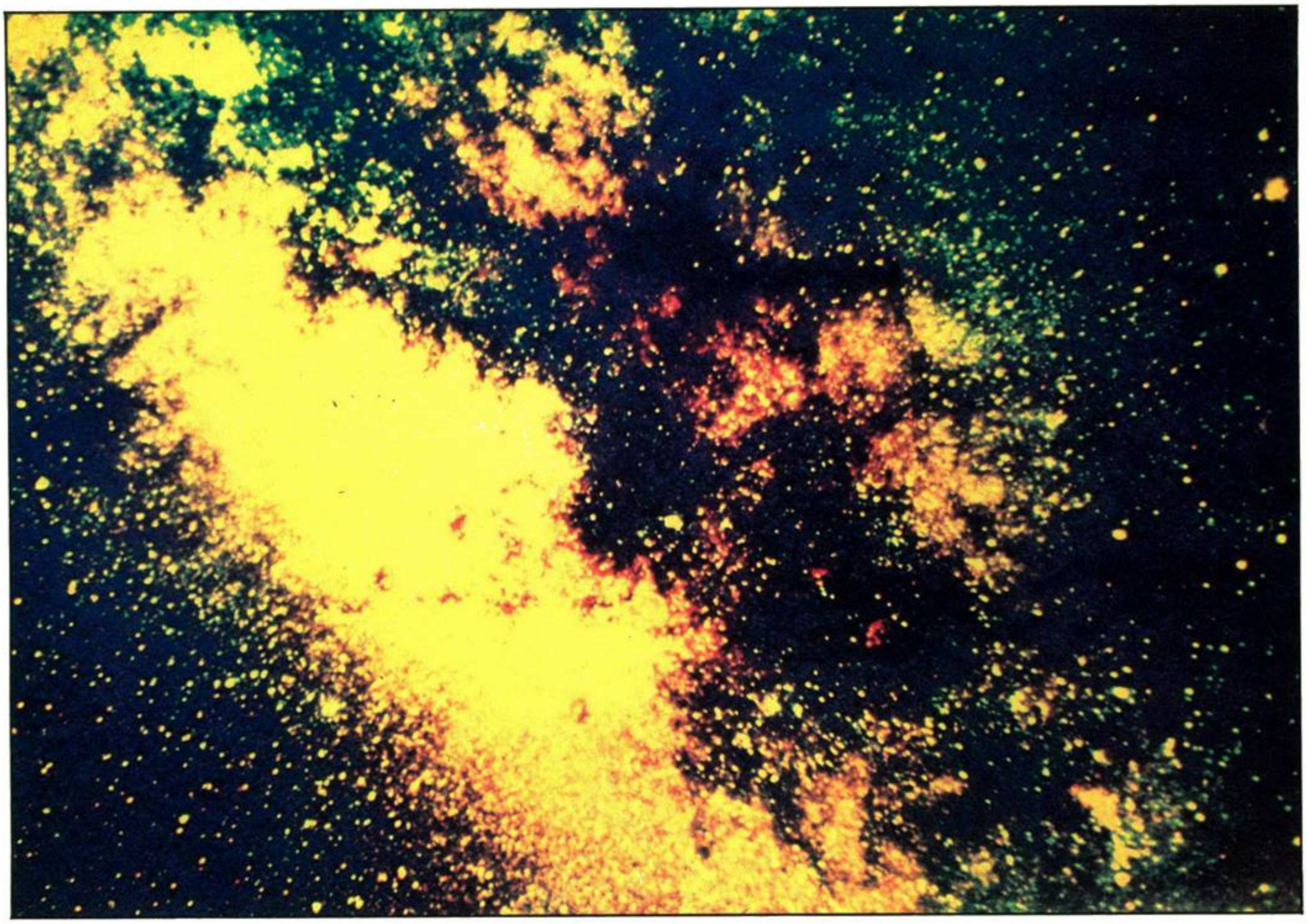
Do the same with the blue and green slides (see the diagram on page 51) to generate the yellow and magenta negatives. Shoot these copies identically so the image scale comes out exactly the same in each. Process the film in color negative chemistry, either K-2 or C-41. Select the three color negative frames that show the most detail.

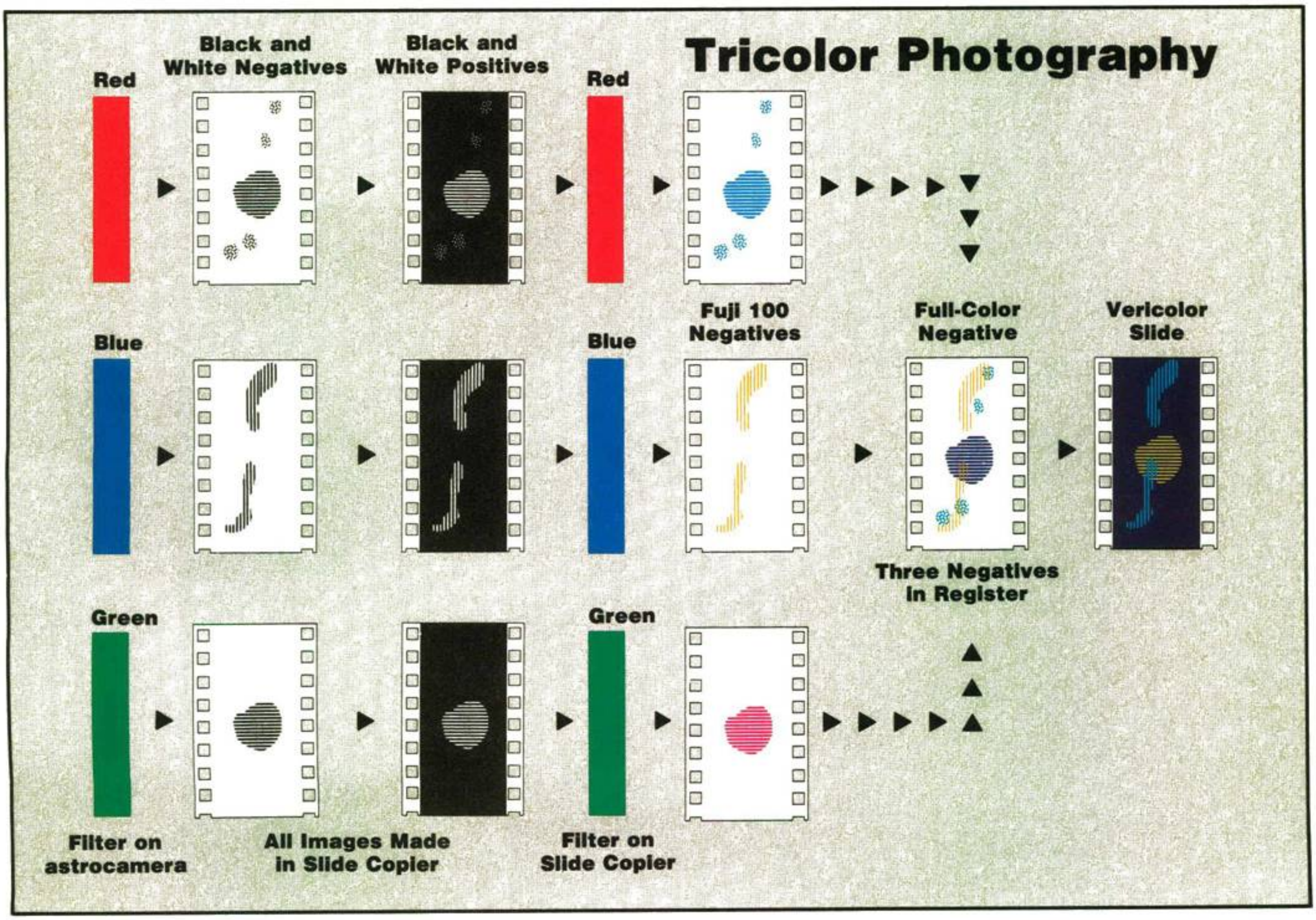
Now, here's the advantage of doing tricolor this way. Using a slide mount that presses your negatives between two thin pieces of glass, tape the edges of the cyan negative onto one side of the glass mount. Using a magnifier (a light board also helps a great deal), tape down the yellow negative image in precise alignment with the cyan image, then do the same with the magenta negative.

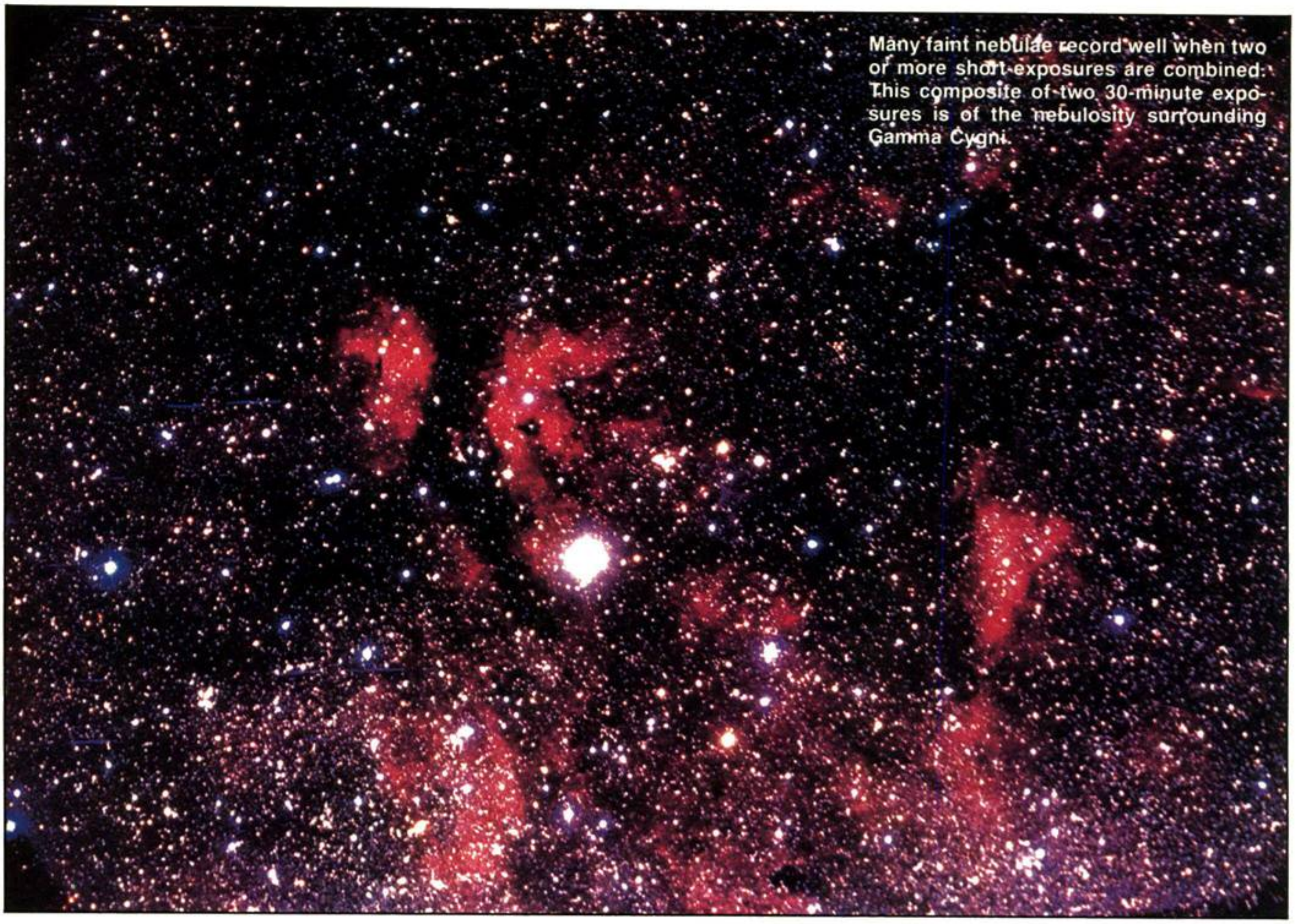
After you're sure all three images are in register, snap on the other half of the glass mount to hold the negatives closely together. Double-check your registration and correct it if your images are not aligned. You now have a composite negative containing all three colors. Print it as you would any other color negative or use Kodak Vericolor 5072 film to produce a full-color slide.

(Vericolor is a low-speed, high-contrast, color negative film with a colorless base.

Right top: This tricolor photo of the Sagittarius region was made by combining 25-minute red, 120-minute blue, and 90-minute green exposures in a slide copier. All photos by Mace Hooley.

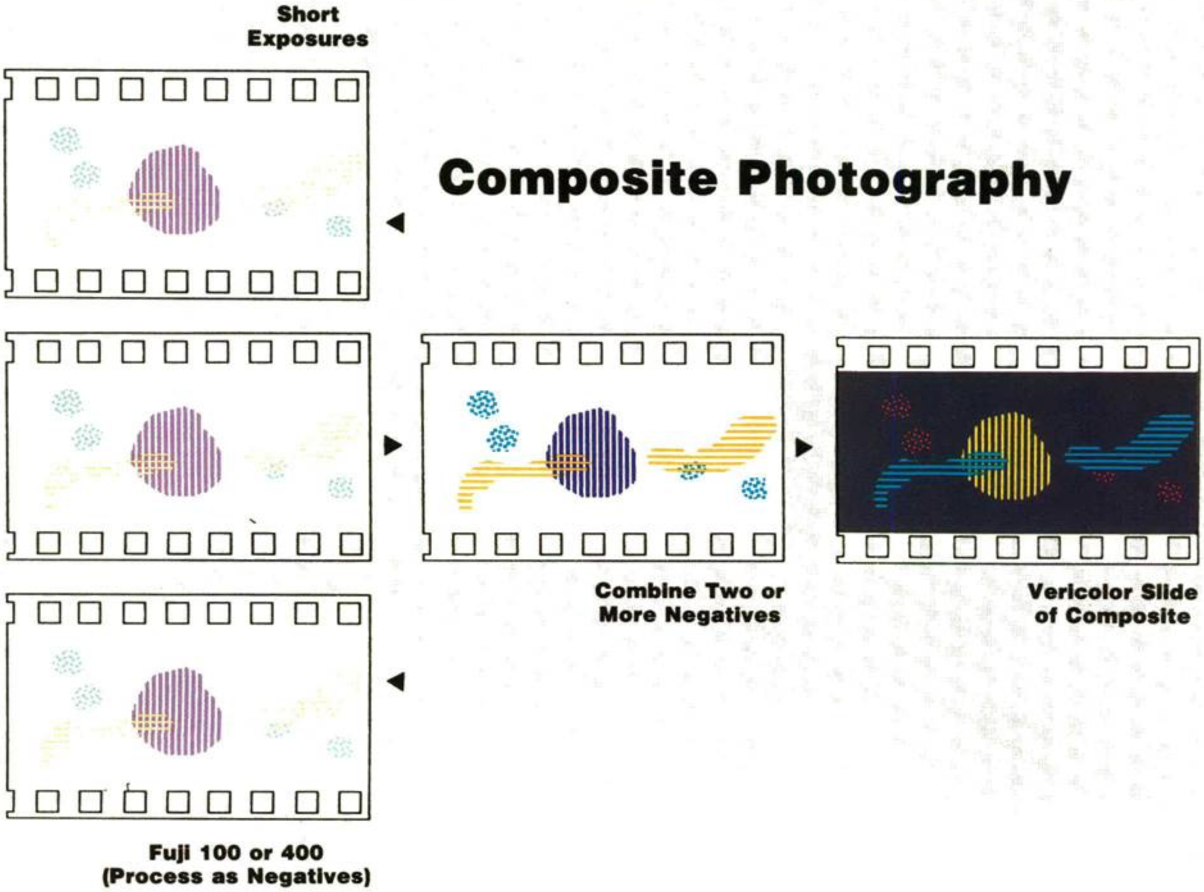


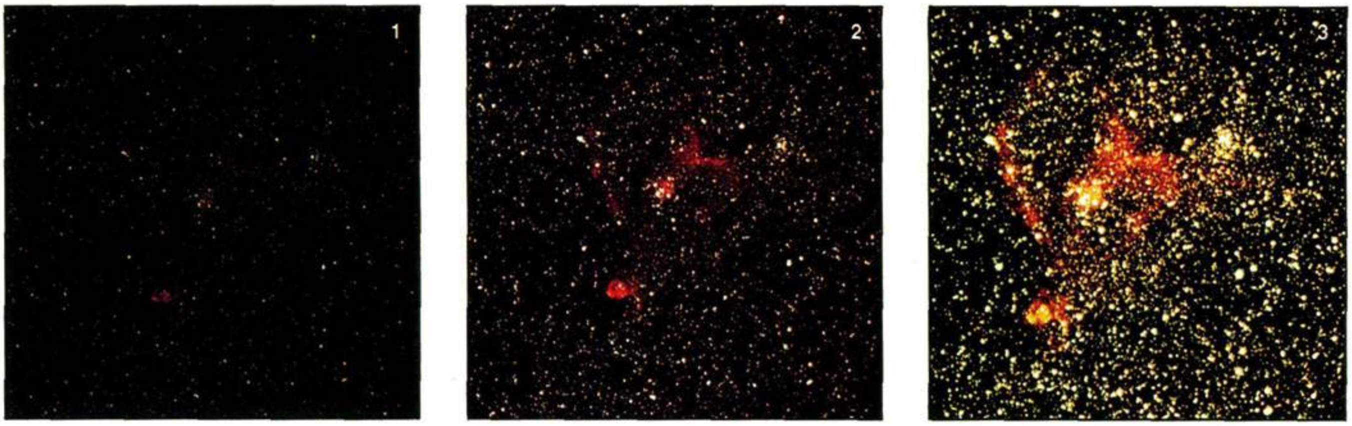

Tricolor Photography
Red
Black and White Negatives
Black and White Positives
Red
Blue
Blue
Fuji 100 Negatives
Full-Color Negative
Vericolor Slide
Three Negatives In Register
Green
Green
Filter on astrocamera
All Images Made in Slide Copier
Filter on Slide Copier

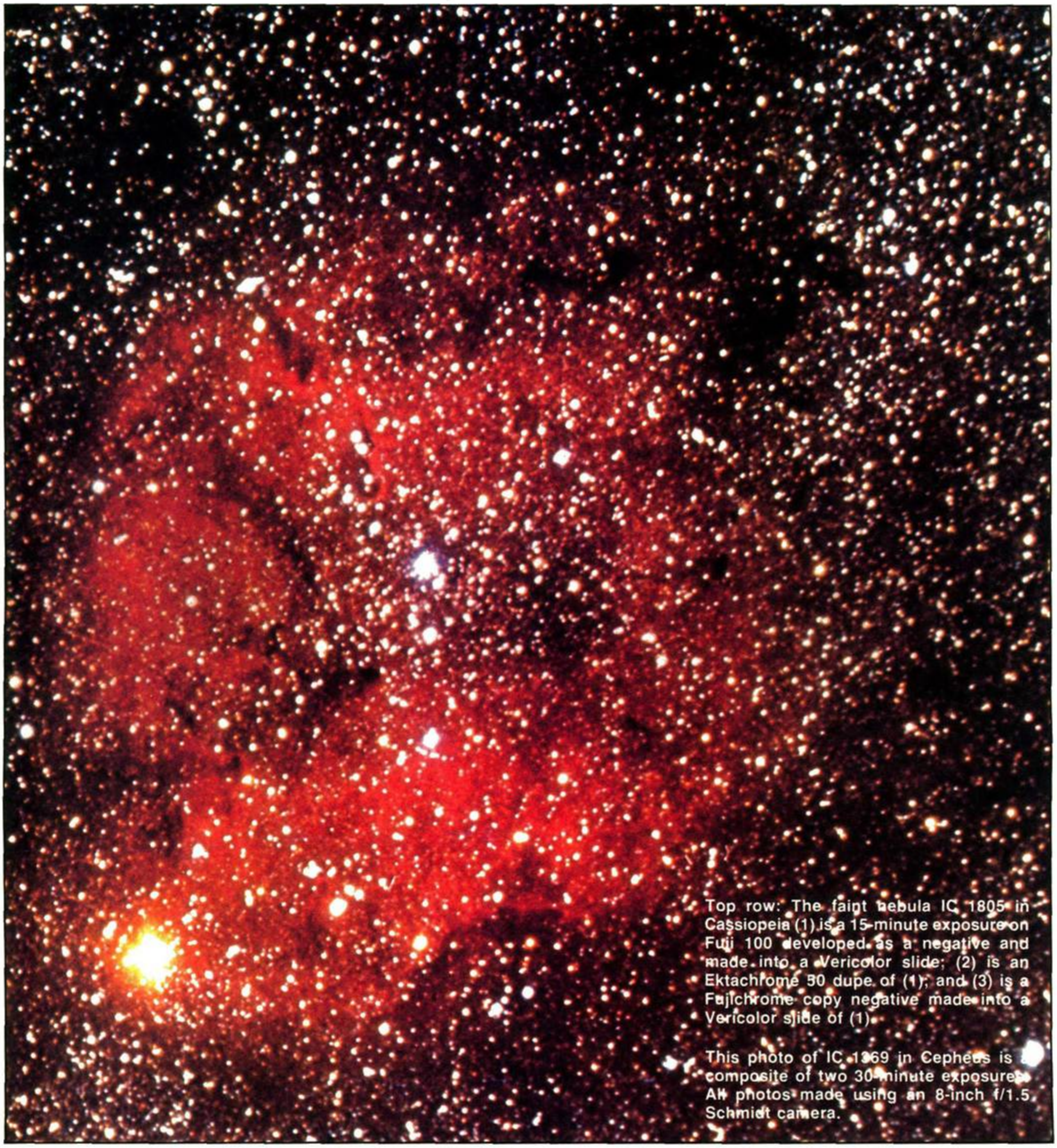


Many faint nebulae record well when two or more short exposures are combined. This composite of two 30-minute exposures is of the nebulosity surrounding Gamma Cygni.

Composite Photography

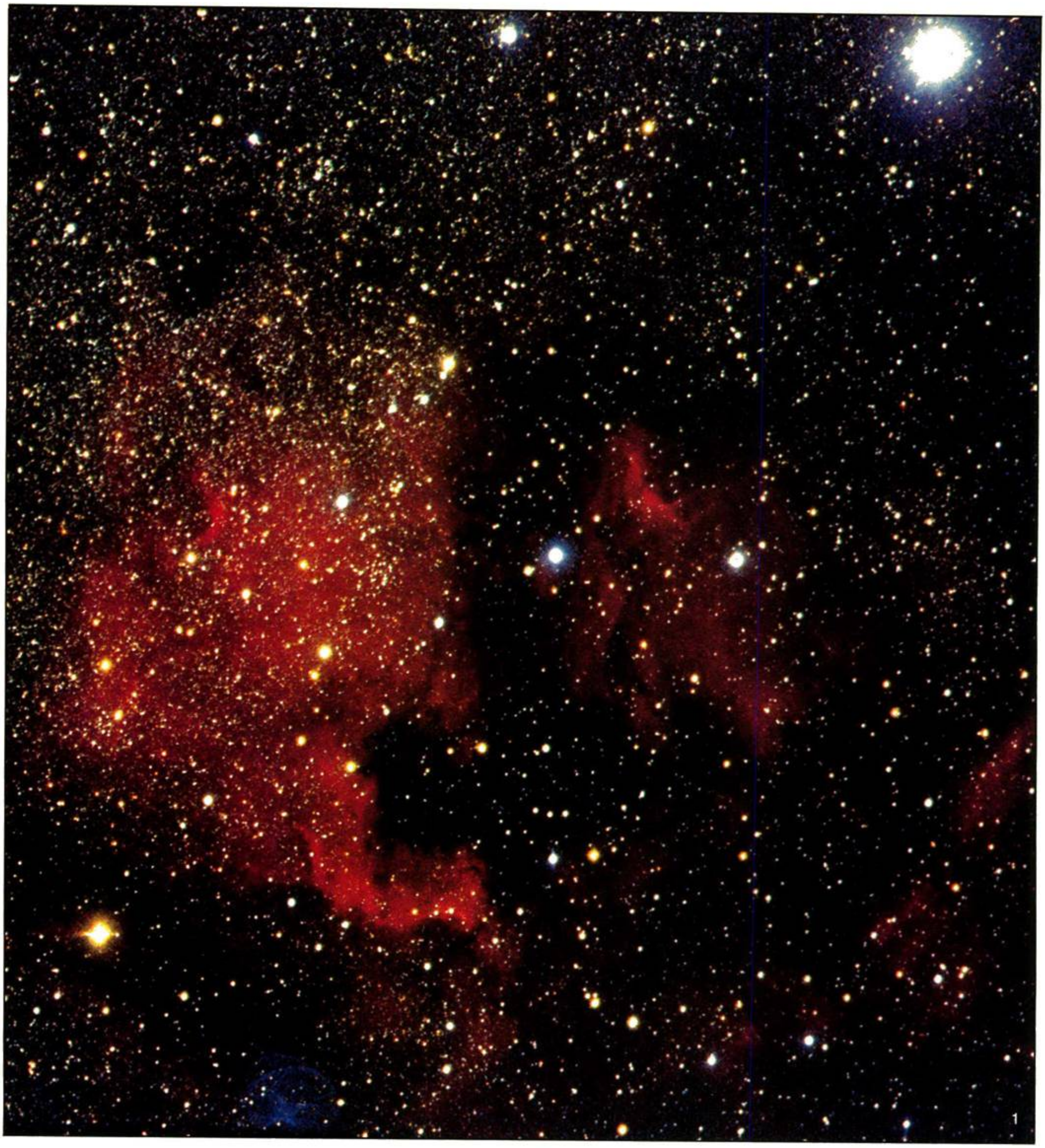

Short Exposures
Combine Two or More Negatives
Vericolor Slide of Composite
Fuji 100 or 400 (Process as Negatives)



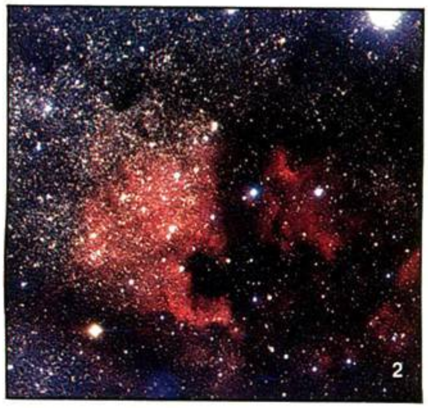


Top row: The faint nebula IC 1805 in Cassiopeia (1) is a 15-minute exposure on Fuji 100 developed as a negative and made into a Vericolor slide; (2) is an Ektachrome 50 dupe of (1); and (3) is a Fujichrome copy negative made into a Vericolor slide of (1).

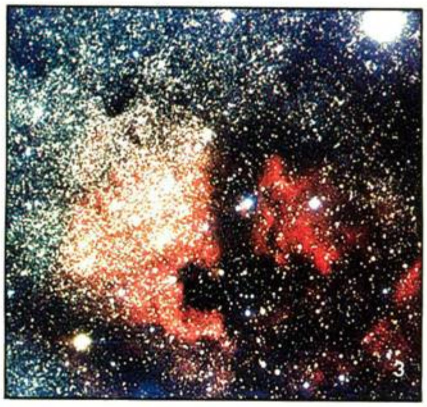
This photo of IC 1369 in Cepheus is a composite of two 30-minute exposures. All photos made using an 8-inch f/1.5 Schmidt camera.



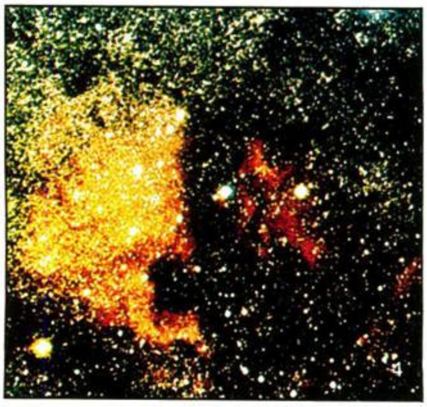
1



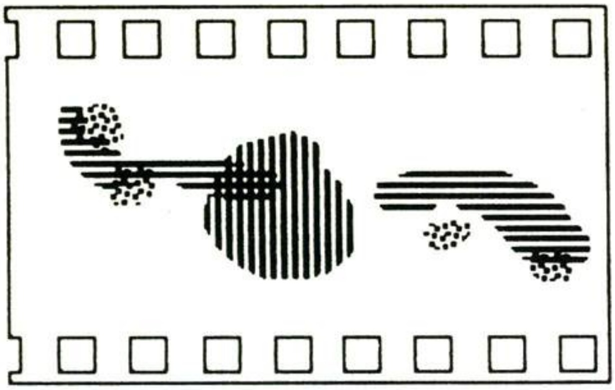
2

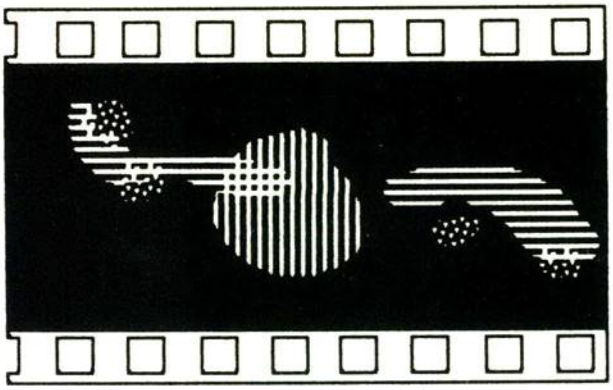


3



4





It can be purchased at most film supply houses and some mail-order photo companies in bulk quantities or 36-exposure rolls. Making Vericolor slides can be quite complicated, involving color balancing the negative with filters. Instructions are usually included with the film.)

The beauty of tricolor photography is that you get great color slides without an enlarger or copy stand, and you can check registration at each step along the way. If you end up with too much contrast, copy your Tech Pan negatives onto a lower contrast film like Panatomic-X instead of Tech Pan, or use low-contrast Kodak Technidol LC developer instead of D-19 to process the Tech Pan black-and-white positives. This will drop the contrast of the final scene. Because this technique yields very high contrast, the brighter star clouds and nebulosity will likely burn out on some tricolor shots, but the fainter objects will show rich colors.

What are the drawbacks of tricolor photography? The three color exposures per finished photograph are lengthy and there is some loss of resolution in each duplication made. Of course, if you had an 8x10 or 11x14 negative as the pros have, you wouldn't suffer a noticeable loss of sharpness. Still, you will be surprised at how well your tricolor photos turn out.

Composite Photos

In a normal deep-sky photograph one long exposure "builds up" the light from an object until it is dense enough to show on the film. Although the object will begin recording before the sky fog does, its image is usually not sufficiently dense to be printable before the sky fog also begins to record. When you increase the exposure time to get a printable image, you also record a great deal of sky fog, thus yielding a poor separation between object and background fog.

So instead of making one 30-minute exposure, make three separate 10-minute exposures. If the sky fog does not show up on exposures shorter than 10 minutes, very little sky fog will be recorded. Your object, though, will record for 10 minutes. Three such exposures will nearly equal the object's final density in a 30-minute exposure, but the sky fog won't be there, or at worst it will be a tiny fraction thereof. The result is a significant gain in image contrast.

Opposite page: The North America Nebula responds well to all types of manipulation. In this series (1) is a single 15-minute exposure on Fuji 100; (2) a composite of two 10-minute exposures; (3) an Ektachrome 50 dupe of (2); and (4) a Fujichrome copy negative and Vericolor slide of (1). An 8-inch Schmidt camera and 40cc magenta filter was used for the original negatives.

Many faint, extended objects can be photographed this way. The emission nebula NGC-6820, just west of the Dumbbell Nebula (M-27), does not show on single long exposures (unless made under a very dark sky), but it is revealed surprisingly well using the composite technique. And although much of the faint nebulosity in the Antares region is lost in sky fog during single exposures, this nebular complex extends more than 6° in a composite photo.

Another plus is that field rotation, one of the banes of astrophotographers, is reduced by a factor of two or three. You can "un-rotate" the individual exposures when the separate negatives are registered. Also, properly registered, the stellar sizes do not grow as they do in a single long exposure; they remain about the size they would be if the total exposure time equalled a single exposure time. Film grain is also averaged over the multiple images, not the rock-hard grain of a single layer of emulsion, and so gets smoothed out somewhat.

Be sure to make all of the exposures of an object at one session so they will register correctly. Distortions inherent in the optical system may make the images unregisterable if you change the system or switch guide stars.

Image Enhancement

Spectacular results can be obtained from many existing transparencies. The only requisite is that the object be visible on the original slide. Red objects are usually enhanced the most, but all colors benefit from this treatment.

Image enhancement involves re-photographing your original transparency onto the Fujichrome 100 slide film, processing it as a negative, and then making a color print or slide using Kodak Vericolor 5072 film. Fuji 100's high contrast and red sensitivity give the same striking results when you use it to copy as it does in an astrocamera.

Place your slide in your slide copier, making sure the light source is daylight-balanced and your light meter is set to ISO 200. Bracket the exposure about three stops around the camera's meter-recommended exposure. Process the film as a negative and select the frame that has the longest tonal range — that is, the one that shows the most shadow and highlight detail — and make a Vericolor slide or a print from that one. You'll probably be amazed at the boost in color separation and contrast gain.

There are some drawbacks to image enhancing, however. Grain really jumps out at you and the bright star images almost quadruple in size, though the smallest stars remain small. Because of this, the technique works best with large, extended objects, like the Helix Nebula, that cover most of the film frame.

Should you need a slight contrast boost, or if you do not want to pay the loss-of-resolution penalty, simply copy your transparency onto Ektachrome 50 (a film that's tungsten-balanced) to raise the contrast and color saturation to acceptable levels. As always, be sure to bracket your exposures. You'll find that overexposure lightens a dark slide and brings out faint detail. Notice, too, that both tricolor and composite photography can be used in conjunction with the enhancement technique for extra color saturation and contrast.

Like any form of photography, astrophotography is open to artistic interpretation and scientific accuracy, whichever suits your pleasure. Regardless of the techniques you use, you are manipulating an image of an object that is of magnificent proportions. Capturing the subtlety of a reflection nebula, a glowing protostellar dust cloud, or a sliver of galactic light from millions of light-years away gives astrophotographers a special feeling that they are a part of the universe. Astrophotographers preserve this feeling on film for all to share.

Mace Hooley is an astrophotographer living in Phoenix, Arizona. His last article, "Processing Astroslides Yourself," appeared in the September 1986 issue.

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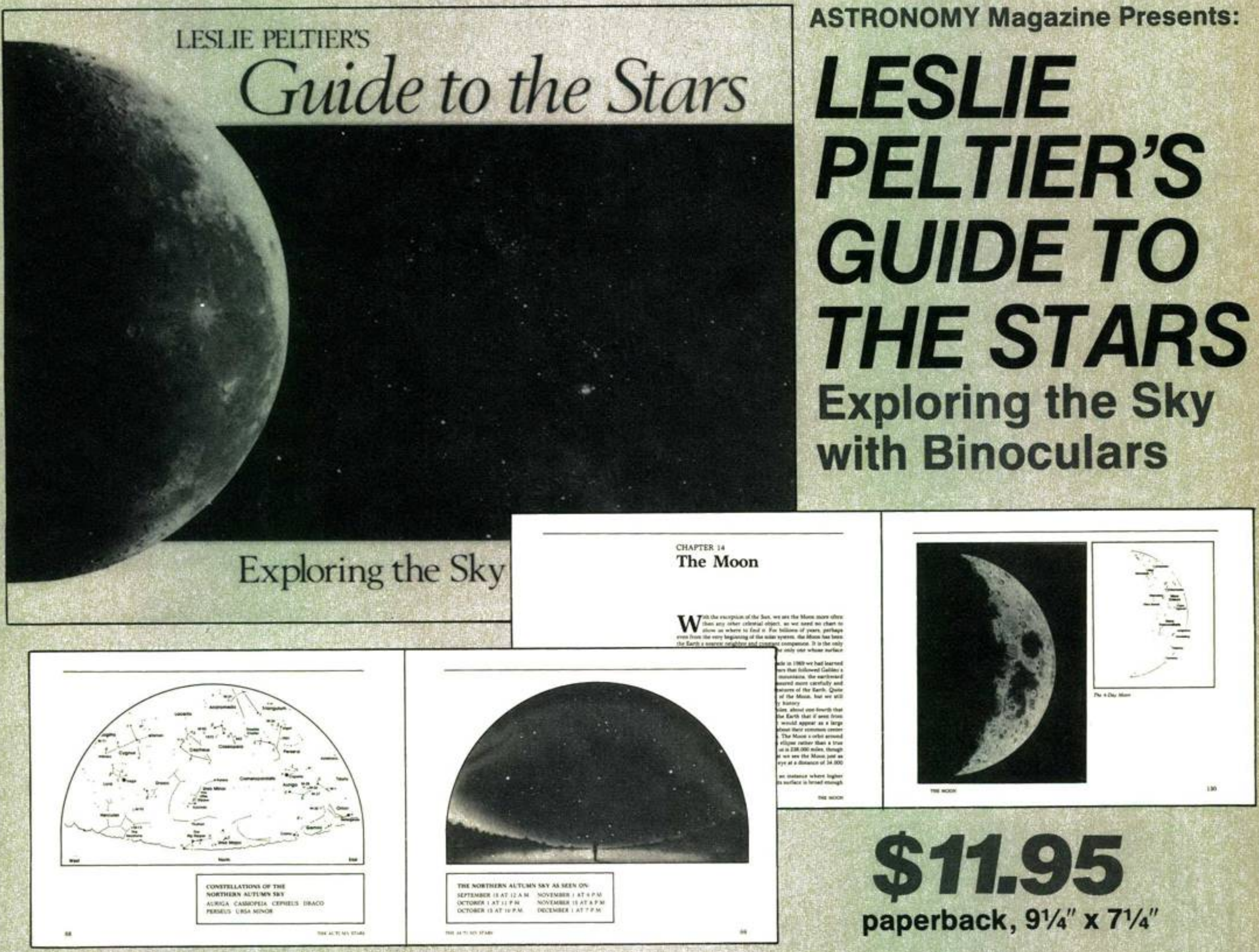

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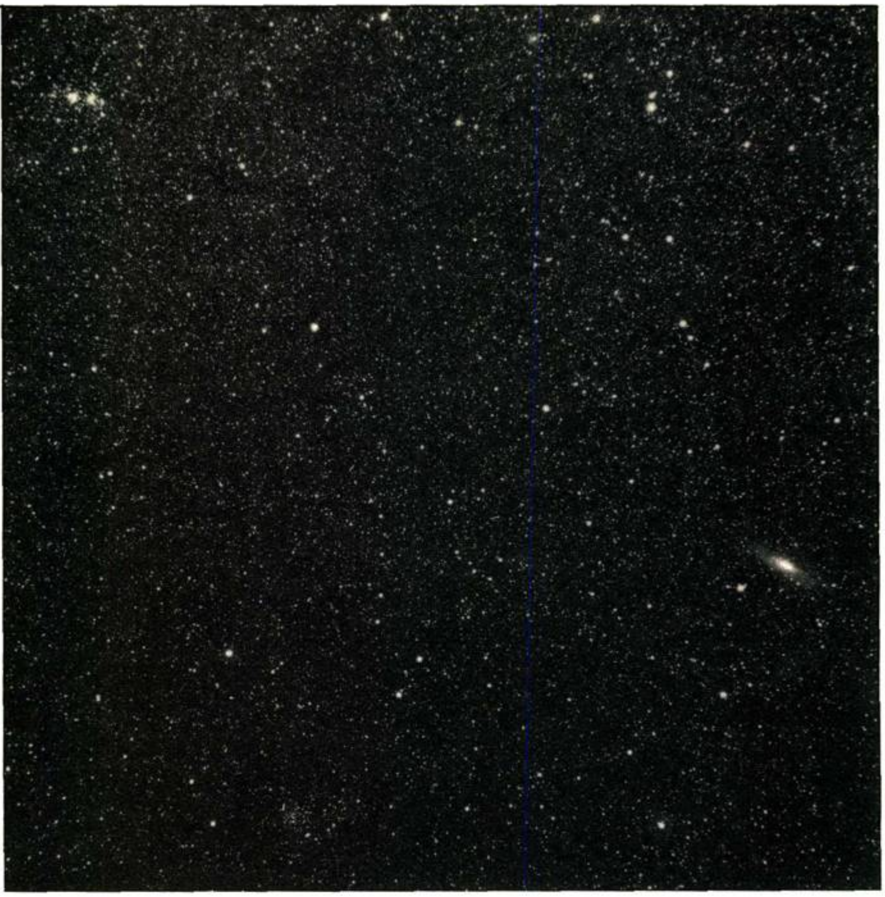
Mercury in the Morning Sky

by Robert Burnham



Above: Scanning the Perseus–Andromeda region of the sky with 7x50 binoculars, you should be able to see the Double Cluster (upper left), the spiral galaxy M-31 (lower right), and the scattered cluster NGC-752 (lower left). Photo by James M. Baumgardt.

Right: The Great Square of Pegasus, seen rising in this star-trailed photo, is high overhead in the evenings this month. Photo by Dale Lightfoot.

The Wanderers

The best star and planet-watching this month comes during two dark periods of the Moon, from the 1st to the 8th (when the Moon is between New and First Quarter and sets soon after the Sun) and from the 24th to the 30th (between Last Quarter and New, when the Moon rises in the wee hours of the morning).

Pick a clear evening for a trip into the countryside. Bring warm clothes, your copy of ASTRONOMY, and a flashlight with its lens dimmed by red cellophane. Include a pair of binoculars and a thermos of hot coffee or cocoa, too. Then find a little-used side road well away from traffic.

Mars and Jupiter are the two bright "stars" in the southeast as evening twilight ends. **Mars** is the dimmer and ruddier one to the west. It has a brightness of −0.2 magnitude, far outshining the 1st-magnitude star to the southeast, Fomalhaut, in Piscis Austrinus.

Each night Mars lies a little farther east, though it may take several evenings before you notice a change. Mars is moving in front of the stars of Capricornus. On the 5th and 6th it will slide south of Iota (ι) Capricorni, and on the 14th and 17th it will overtake Gamma (γ) and Delta (δ) Capricorni.

Appearing almost motionless, **Jupiter** is nestled in Aquarius, the zodiacal constellation east of Capricornus. Jupiter shines brilliant white at magnitude −2.6. Looking quickly from Jupiter to Mars makes the latter's amber color readily apparent.

To see Mercury and Venus, get up before dawn and go to a viewing site with an uncluttered southeastern horizon. After conjunction with the Sun on November 5, **Venus** rapidly takes up a prominent place in the predawn sky. You can spot −4.5-magnitude Venus low in the southeast by the 15th.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

On November 13 **Mercury** also moves into the predawn sky, but before it does a rare event takes place: Mercury transits the face of the Sun. Unfortunately, the transit occurs during nighttime for North America. (For more details, see Gazer's Gazette on page 107.)

Afterward, Mercury will give its best show of the year, appearing in the southeastern sky during the hour before sunrise. It will be visible from about November 18 to December 22. Best visibility occurs on November 30 when −0.5-magnitude Mercury will lie to the left of Venus at about half its elevation. On the 29th and 30th a slim crescent Moon will move into the area — good photo material. Use a medium-size telephoto lens and a steady tripod. Exposures of ½, 1, 2, 5, and 10 seconds, all at fully open aperture, should net you something no matter what your film is.

Two meteor showers occur in November, the **Southern Taurids** (which peak on the 3rd) and the **Leonids** (the 18th). Of the two the Southern Taurids offer better viewing. Observers at a dark-sky site should see about fifteen meteors an hour during the moonless early morning of the 3rd. The meteors' radiant lies in southwest Taurus, near the Pleiades.

Regrettably, on the night of the Leonid's peak activity (November 17/18) the Full Moon will lie near the radiant, which is the "sickle" asterism in Leo.

The Starry Sky

Befitting the lateness of the season, the south and western sky displays the lingering autumn stars while the east is filling up with winter's. The Star Dome map shows the sky in mid-evening, with the last glow of twilight gone and night fully upon us.

As you face due west, a conspicuous white star hovers above the horizon. This is Altair in **Aquila** the Eagle. To the right of Altair lies another bright white star called Vega. It marks one corner of **Lyra**, Orpheus' celestial Lyre. Above Lyra glides the lanky form of **Cygnus** the Swan, with 1st-magnitude Deneb in its pin feathers. Cygnus is sometimes called the Northern Cross.

Straight above Altair lies little **Delphinus** the Dolphin. Its rhomboidal head bears the alternate name of "Job's Coffin."

November Night Sky

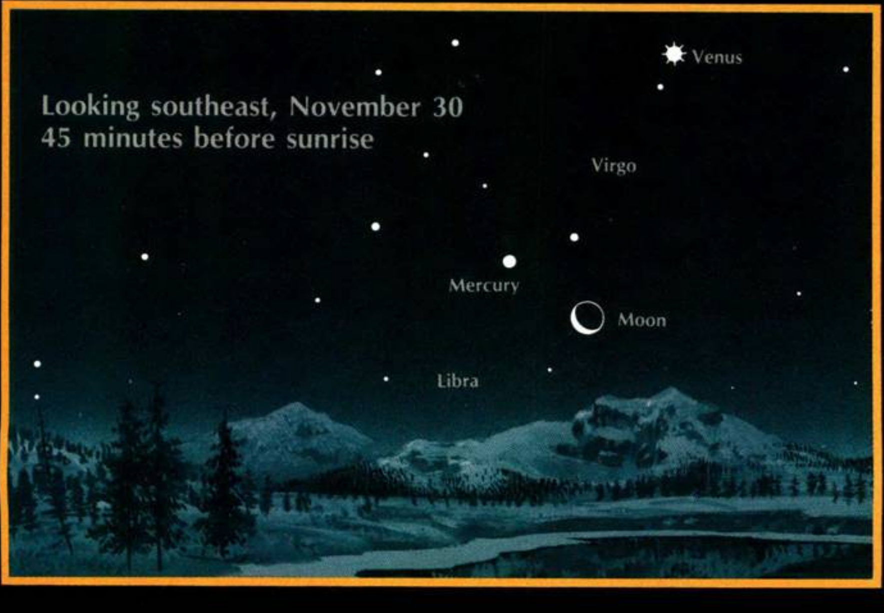
New Moon
November 2
1:02 a.m. EST

First Quarter
November 8
4:11 p.m. EST

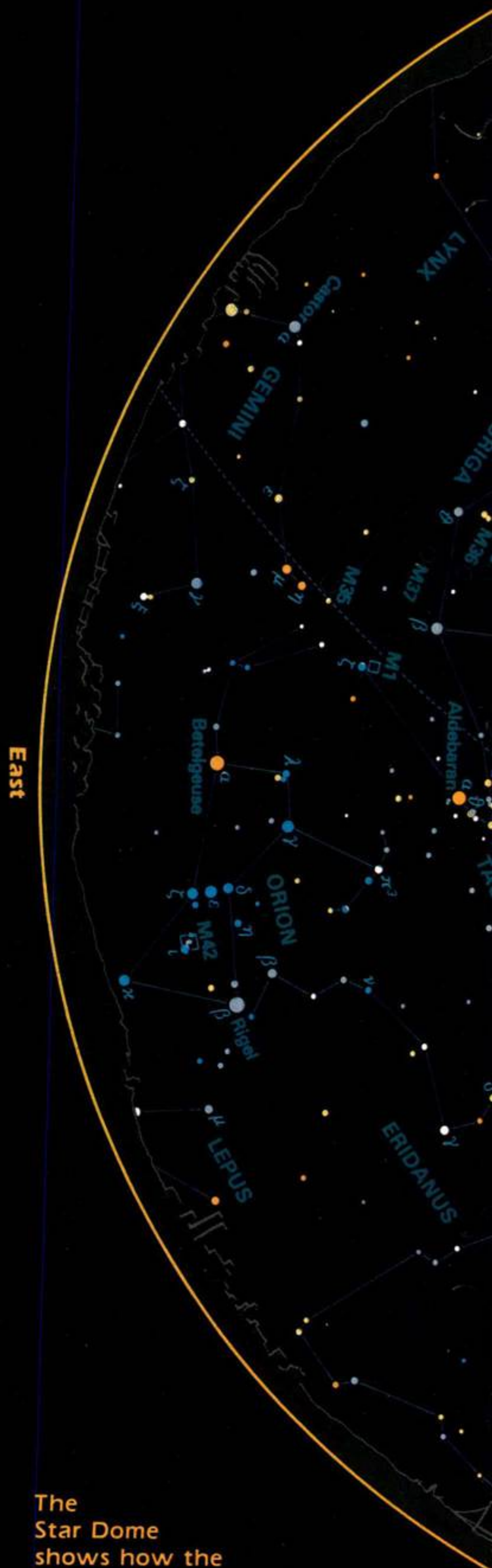
Full Moon
November 16
7:12 a.m. EST

Last Quarter
November 24
11:50 a.m. EST

2nd	New Moon occurs at 1:02 a.m. EST.
3rd	The Moon is closest to Earth at 9:30 p.m. EST: 361,806 kilometers. Peak of activity for the Southern Taurid meteor shower. Look for about 15 meteors per hour coming from the area of sky southwest of the Pleiades.
5th	Venus passes through inferior conjunction, thereby shifting from the evening sky into the morning. It will become visible low in the southeast just before sunrise in about ten days.
8th	First Quarter Moon is at 4:11 p.m. EST. The Moon passes 3° south of Mars this evening.
10th	The Moon lies to the east of Jupiter.
13th	Mercury passes through inferior conjunction and transits the face of the Sun. The transit is generally not visible from the Western Hemisphere. See Gazer's Gazette on page 107 for details.
16th	The Moon is Full at 7:12 a.m. EST.
18st	The predawn hours mark the peak of activity for the Leonid meteor shower. Moonlight will interfere, however, and reduce the number of meteors seen.
19th	The Moon is farthest from the Earth at 5:14 p.m. EST: 406,018 kilometers.
20th	Start looking for Mercury low in the southeast during the hour before sunrise. It will be at peak elevation and visibility on the 30th.
24th	Last Quarter Moon occurs at 11:50 a.m. EST.
30th	Mercury is at greatest elongation from the Sun in the morning sky and will remain in sight for three weeks.

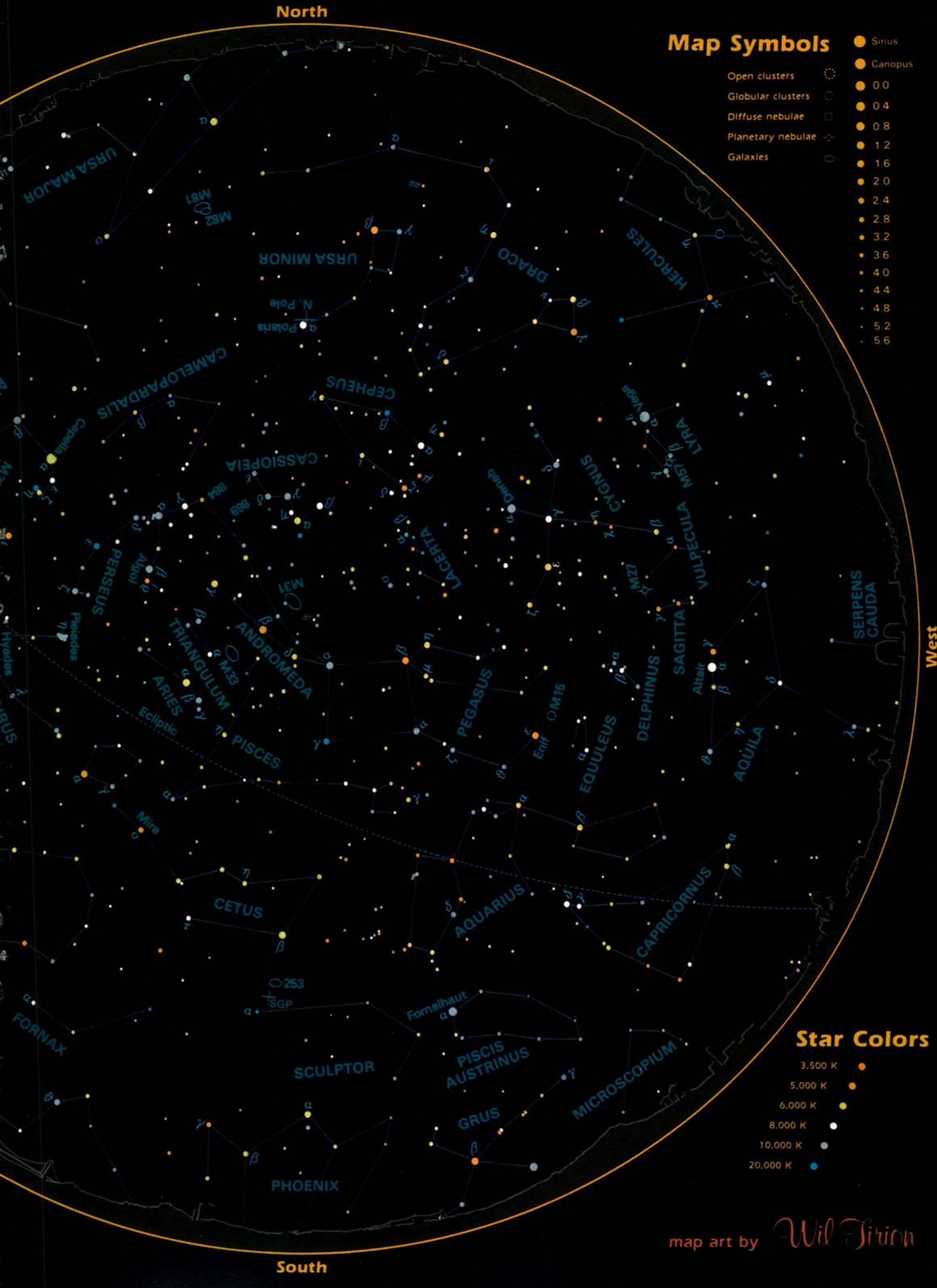


Looking southeast, November 30
45 minutes before sunrise



The
Star Dome
shows how the
sky looks at:

9:00 p.m. on November 1
8:00 p.m. on November 15
7:00 p.m. on November 30


North
Map Symbols
Sirius
Canopus
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
URSA MAJOR
M81
M82
URSA MINOR
N. Pole
Polaris
DRACO
HERCULES
CAMELOPARDALIS
CEPHEUS
Capella
CASSIOPEIA
884
869
Vega
LYRA
M57
Deneb
CYGNUS
PERSEUS
Algol
M31
LACERTA
VULPECULA
M27
SAGITTA
SERPENS CAUDA
Pleiades
Hyades
ANDROMEDA
TRIANGULUM
M33
ARIES
Ecliptic
PISCES
PEGASUS
M15
Enif
EQUULEUS
DELPHINUS
Altair
AQUILA
West
Mira
CETUS
AQUARIUS
CAPRICORNUS
253
SGP
Fomalhaut
FORNAX
SCULPTOR
PISCIS AUSTRINUS
MICROSCOPIUM
GRUS
PHOENIX
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
South

map art by Wil Tirion

Left: The zig-zag outline of Cassiopeia is seen poised above an observatory in this photo by Jerry Schad. The crescent Moon and a flashlight illuminated the dome for this 40-second exposure using 3M 1000 film through a 35mm lens at f/2.

Between Delphinus and Jupiter stands the Foal **Equuleus**, which some ancient cosmographers included with the Dolphin. Ruddy Mars lies in **Capricornus** the Sea-Goat, a mythical animal with the forequarters of a goat and the tail of a fish. Its star pattern makes a broad triangle, with Alpha (α) Capricorni at one tip being a nice double star in binoculars.

Capricornus and **Aquarius** both lie in the zodiac, the path of the Sun and planets during the year. Right now brilliant Jupiter is in Aquarius, making the Water-Carrier's dim pattern difficult to trace. To the left of Mars we see a bright star — Fomalhaut, the Mouth of **Piscis Austrinus** the Southern Fish.

Above Jupiter notice a rough circle of six stars about the size of your fist held at arm's length. This is the western of the two Fish in zodiacal **Pisces**. A ribbon of 3rd- and 4th-magnitude stars stretches eastward to the constellation's brightest star, Alpha (α), named Alrisha, "the Knot." From Alrisha, a second ribbon snakes northward to entwine the other Fish.

Pisces forms a "V" that embraces the Flying Horse **Pegasus**, which is most easily found by locating its Great Square. The Square represents the Horse's body and wings (he's upside down), and the stars Zeta (ζ), Theta (θ), and Enif delineate his neck, head, and nose, respectively. His legs extend from Beta (β) down toward Delphinus.

Below Alrisha lies a celestial whale, **Cetus**. The star labeled Mira ("the Wonderful") in Cetus' tail changes brightness from 3rd magnitude to 9th and back, all in about eleven months. Right now Mira is invisible to the unaided eye, but as the winter months slip by keep a lookout for this star's reappearance.

Viewers in the southern United States should hunt for a few austral constellations. East of Fomalhaut is **Sculptor**, barren to the eye but containing NGC-253, a fairly bright spiral galaxy just visible in binoculars. Below Sculptor note the Firebird **Phoenix** and next to it gawky **Grus** the Crane. **Fornax** the Furnace offers little to the eye, but neighboring **Eridanus** the River winds south in a stately line.

Rising in the east is mighty **Orion** the Hunter. Orion offers many fine sights but we must wait until it climbs higher to see them. Orion is holding off the charge of **Taurus** the Bull, a zodiacal group on the edge of the Milky Way that is worth exploring with binoculars. The Hyades star cluster forms the Bull's muzzle, with amber Aldebaran as his angry eye. His horns extend east, one of them poking **Auriga** the Charioteer. The renowned Pleiades cluster isn't part of the Bull asterism but is simply lovely on its own.

Let's return to the Great Square of Pegasus. Its upper left star, Alpheratz, really belongs to **Andromeda** the Chained Maiden, depicted by two diverging lines of stars (see Skylore). Near Beta (β) Andromedae lies the spiral galaxy M-31. Under a dark sky it is easily visible to the naked eye as a soft patch of haze.

Triangulum the Triangle and **Aries** the Ram are faint. Compact but dull, Aries is significant only because it lies in the zodiac. Triangulum's M-33 is a spiral galaxy like M-31, but it is more difficult to see. Between these two and the pentagon of Auriga lies a crooked branch of 2nd- and 3rd-magnitude stars, **Perseus** the Hero. Besides its many naked-eye stars, Perseus features the Double Cluster (NGC-869 and -884) and a rich Milky Way background for binoculars.

Lastly, overhead lie **Cassiopeia** and **Cepheus**, two constellations tied in myth to Andromeda. Cassiopeia circles the pole star opposite Ursa Major the Great Bear. Cepheus, shaped like a child's drawing of a house, lies near Cygnus just off the Milky Way.

Skylore

According to the Greeks, Andromeda was the lovely daughter of Cassiopeia and Cepheus. Proud of her daughter's beauty and her own, Cassiopeia one day foolishly boasted that both were the fairest that ever lived. This soon reached the unbelieving ears of Hera, the jealous wife of Zeus, and the Nereids, nymph-maiden favorites of Poseidon. They demanded that Poseidon immediately avenge Cassiopeia's *lese majesty*.

Poseidon therefore sent a sea monster, Cetus, to attack Cepheus' kingdom. The monster is now usually depicted as a whale, a large if inoffensive creature, but in the original story Cetus was a cross between a fire-breathing dragon and one of those fearsome, ship-devouring "sea serpents" bred in the darker corners of sailors' imaginations.

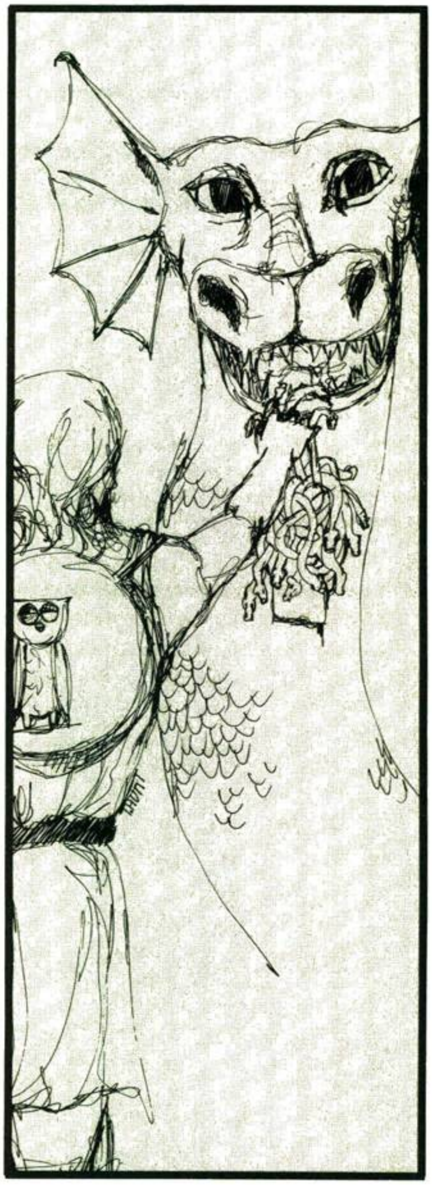
With his kingdom in terror, Cepheus consulted an oracle for advice. The appalling reply: To save the realm, Andromeda must be delivered up to Cetus. Heavy-hearted and bitter over his wife's vanity, Cepheus was forced by his people to comply. The place chosen for the sacrifice was a rugged part of the coast. Stripped naked, Andromeda was chained hand and foot to a large rock to await her grisly doom.

Soon the monster swam by and noticed her. Hissing with delight, he clambered out of the water and slithered across the seaweed-slippery boulders toward the shrieking girl.

Suddenly Cetus felt a sharp, slicing pain. He turned and saw a man behind him armed with a great bronze sword. Again and again the man struck, but as pain lanced through the creature and his blood gushed forth, Cetus felt his strength increasing. Fired with a killing rage, the monster was poised to pound the intruder to bloody fragments.

Then the man did a curious thing. Dropping his sword he reached down, grabbed something unspeakably vile, and shoved it in the monster's face, turning Cetus to stone.

The man — Perseus, a great hero — slowly caught his breath. Then, turning to Andromeda, he struck loose her shackles and warned her not to look at the vile object. It was the head of Medusa, a Gorgon he had just killed and whose face was so hideous that all who looked directly upon it were turned to stone with fear. Next Perseus called down his flying horse Pegasus and, delighted by the girl's beauty, carried Andromeda home to marry her.



Unfortunately, the gods felt that Cassiopeia had gotten off lightly. So they tied her to her throne and condemned her to circle the Pole Star endlessly, alternately sitting right side up and dangling upside down.

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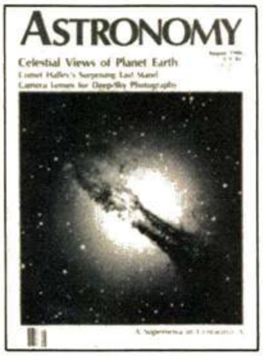
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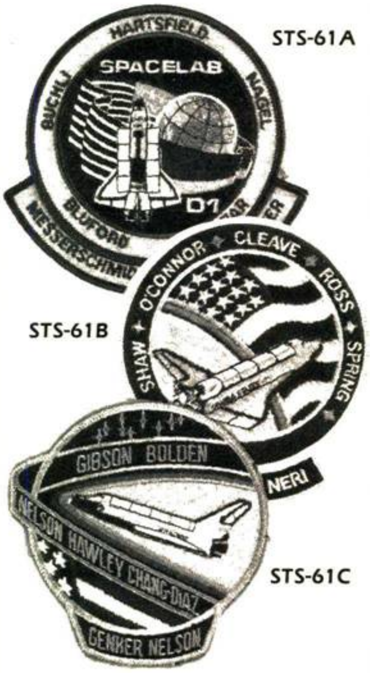

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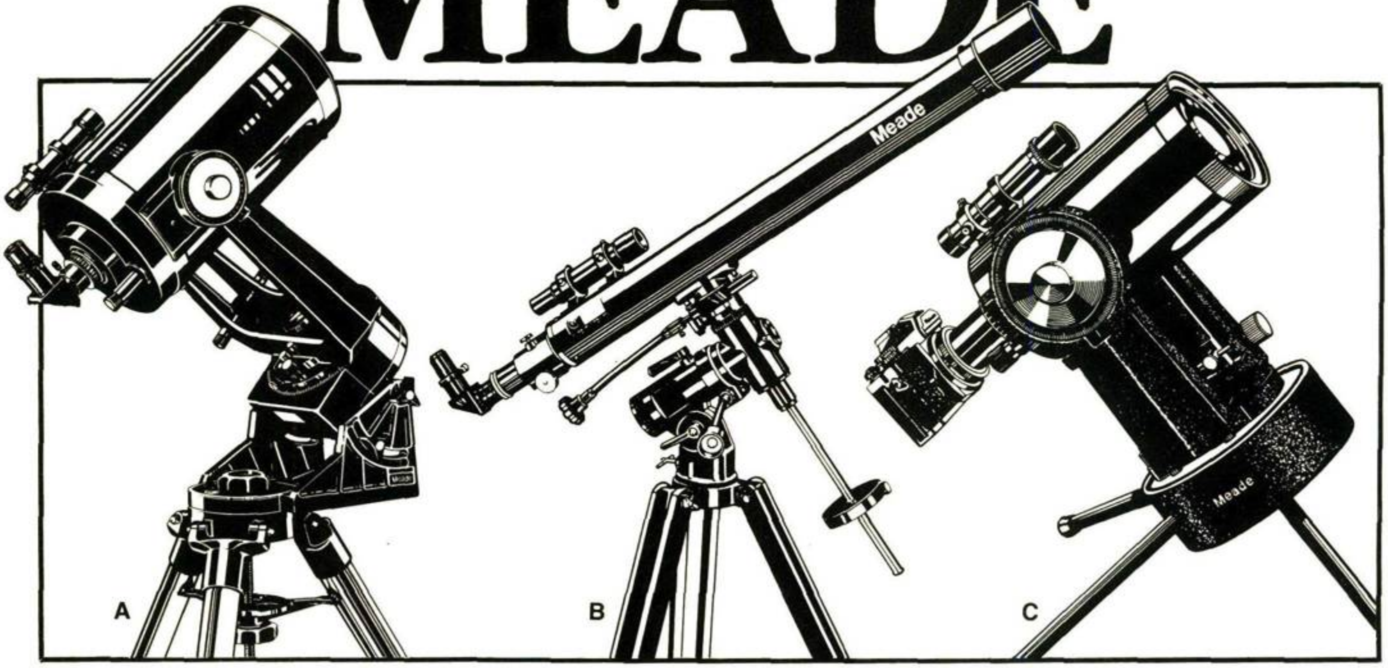

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Eclipse Predictions On Your Computer

by Mark Whiteman

Knowing when Earth's shadow will eclipse the Moon is the first step in obtaining astrophotos like this. Jurgen Knobloch took this time sequence in the French Alps with a 65mm f/4 lens.

Eclipse watchers had the opportunity to see two different kinds of eclipses during October 1986. First there was an annular/total solar eclipse on October 3. Though the path of maximum eclipse was in the Atlantic Ocean between Greenland and Iceland, a large number of observers in North America were able to view a partial eclipse. Fourteen days later the Eastern Hemisphere was treated to a total lunar eclipse.

If you were lucky enough to see either of these spectacular displays or have seen other eclipses in the past, you may have developed a permanent fascination with them. After seeing a partial eclipse of the Sun in 1974, I became hooked on viewing as many eclipses of all kinds as possible.

But finding the dates of upcoming eclipses is not all that easy, and, in fact, many standard reference works don't even bother to list partial eclipses. I decided to use my computer background to write a program that could predict solar and lunar eclipses.

There are a vast number of complex factors that determine when an eclipse will occur. Once the intricacies of orbital motion and position are reduced to a series of calculations, however, a computer can take that information and accurately predict eclipses.

An eclipse of the Sun or Moon occurs whenever the Sun, Moon, and Earth are in a direct line. For a solar eclipse to take place the New Moon must be between the Earth and Sun so that the Moon's shadow is cast on Earth. In a lunar eclipse the Earth is between the Sun and the Full Moon and the Moon passes through the shadow of Earth.

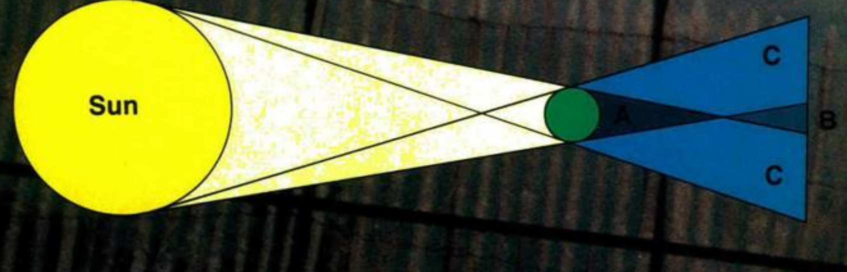
At first glance it might appear that eclipses would occur at every New and Full Moon. However, because the Moon's orbit is tilted at a 5° angle to Earth's orbital plane (the ecliptic), the shadow of the New Moon generally lies north or south of the Earth, and Earth's shadow similarly misses the Full Moon.

An eclipse can only occur where the two orbital planes intersect. These two points on the Moon's orbit are called the nodes of the orbit, and the line joining them is the line of nodes. When the New Moon occurs near a node, its shadow falls on the Earth and we see a solar eclipse. When the Full Moon occurs near a node, the Moon is eclipsed by Earth's shadow. In another way of looking at it, if the Sun lies within a certain angle of the line of nodes, called the ecliptic limits, there will be an eclipse, otherwise there won't.

Such alignments happen approximately every six months and they produce what are known as eclipse seasons. Because of perturbations induced by the Sun, however, the line of nodes slowly precesses (changes orientation relative to the stars), making one circuit every 18.6 years. Eclipse seasons, therefore, occur about twenty days earlier each year.

Because the orbits of the Earth and

When the Moon blocks the Sun's light, an observer on Earth sees a total solar eclipse if he is in region A, an annular eclipse in region B, and a partial eclipse in C. When the Earth casts its shadow and the Moon is at A, we see a total lunar eclipse. With the Moon at C we see a penumbral eclipse. No eclipse is visible from any other region.



How ECLIPSE.BAS Works

The ECLIPSE.BAS program on pages 68 and 69 predicts both solar and lunar eclipses, calculates their circumstances, and prints the data. It is based on the formulae presented in Jean Meeus' *Astronomical Formulae For Calculators, 2nd Edition* (Willmann-Bell, 1982). Written in generic BASIC, ECLIPSE should be readily adaptable to most dialects of BASIC and to other computer languages as well.

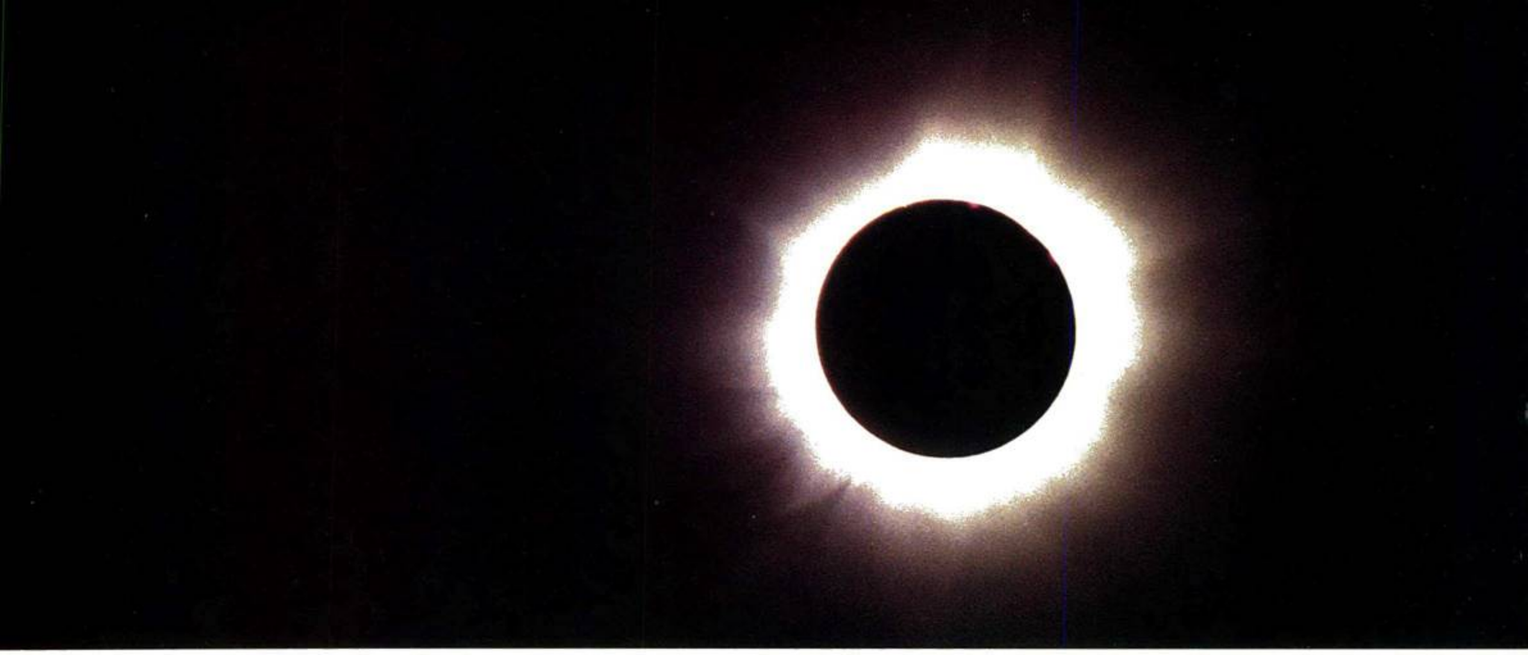
The program begins by asking you for a starting date for the eclipse search, whether you are looking for a solar or lunar eclipse, and if the search should be made forward or backward in time. It then determines how many lunar months have passed since January 1, 1900, an arbitrary starting date chosen because a New Moon occurred on that date.

The computer rounds the number of these synodic months, or lunations, to the nearest integer, which corresponds to the closest New Moon. If a lunar eclipse was chosen, the computer adds 0.5 to the integer to get the next Full Moon.

ECLIPSE next calculates the Julian Date of the New or Full Moon from this lunation number. The computer then determines the orbital positions of the Sun and Moon on this date.

The variable FM is the measure of how close the Moon is to a node of its orbit. If FM is greater than the ecliptic limit of 21°, no eclipse can take place. If the separation is less than 13.9°, an eclipse is certain. Any angle in between these two extremes may lead to an eclipse and has to be investigated further.

If no eclipse occurs on the date checked, the program prints a message to that effect along with the date. The number of lunations is then increased by



```
100 REM ****************** ECLIPSE.BAS ******************
110 REM *                                               *
120 REM *  Lunar/Solar Eclipse Predictor - Copyright    *
130 REM *  1984 by Mark Whiteman. Written in BASIC      *
140 REM *  Version 5.20 on a CP/M-80 2.22 system.       *
150 REM *  Published in ASTRONOMY - November 1986.     *
160 REM *                                               *
170 REM *************************************************
180 REM FUNCTION TO PUT ANGLE X IN 0-360 RANGE
190 DEF FN LESS(X)=((X/360)-FIX(X/360))*360
200 DIM TI%(14),UR(5),SD(5)
210 REM RA IS PI/180. USED TO CONVERT DEGREES TO RADIANS
220 RA=.0174532925#
230 PRINT:PRINT:PRINT
240 REM CALL INPUT SUBROUTINE
250 GOSUB 2360
260 REM CALL DAY-OF-YEAR SUBROUTINE. PUT IN "DO"
270 GOSUB 2550
280 Y2=Y%+(DO%/365)
290 REM CALCULATE K LUNATIONS SINCE 1/1/1900
300 K=(Y2-1900)*12.3685
310 K3=ABS(K-FIX(K))
320 IF K<0 THEN K3=K3+1
330 REM SEE IF WE SHOULD ROUND UP OR BACK A LUNATION
340 IF (K3>.5) AND (LS$="S") THEN K=K+.5*SGN(K)
350 REM IF LUNAR - ADD 1/2 LUNATION TO K
360 REM IF K<0 WE MUST SUBTRACT 1/2 LUNATION
370 IF LS$="L" THEN K2=.5 ELSE K2=0
380 K=FIX(K)+K2*SGN(K)
390 T=K/1236.85
400 REM CALCULATE MEAN ANOMALY OF SUN, MOON; ARG OF LATITUDE
410 REM AND MULTIPLY BY RA TO GET RADIAN MEASURE
420 SM=359.2242#+29.10535608000003#*K-.0000333*T^2-3.47E-06*T^3
430 SM=FN LESS(SM)
440 SM=SM*RA
450 MM=306.0253#+385.81691806#*K+.0107306*T^2+1.236E-05*T^3
460 MM=FN LESS(MM)
470 MM=MM*RA
480 FM=21.2964+390.67050646#*K-.0016528*T^2-2.39E-06*T^3
490 FM=FN LESS(FM)
500 FM=FM*RA
510 REM CALCULATE JULIAN DATE OF POSSIBLE ECLIPSE MOON
520 REM JW=WHOLE NUMBER PART OF JULIAN DAY
530 REM JD=DECIMAL PART OF JULIAN DAY NUMBER
540 JD=.75933+.53058868#*K+.0001178*T^2-1.55E-07*T^3
550 JD=JD+.00033*SIN((166.56+132.87*T-.009173*T^2)*RA)
560 REM IF ECLIPSE LUNAR - ADD .5 FOR 1/2 LUNATION
570 IF LS$="L" THEN JD=JD+.5
580 JW=FIX(2.41502E+06+29*K)
590 REM CALCULATE JD CORRECTION TO OBTAIN MAX ECLIPSE JD
600 MX=(.1734-.000393*T)*SIN(SM)+.0021*SIN(2*SM)
610 MX=MX-.4068*SIN(MM)+.0161*SIN(2*MM)
620 MX=MX-.0051*SIN(SM+MM)-.0074*SIN(SM-MM)
630 MX=MX-.0104*SIN(2*FM)
640 JD=JD+MX
650 JW=JW+FIX(JD)
660 JD=JD-FIX(JD)
670 REM CALL JD-TO-CALENDAR CONVERSION SUBROUTINE
680 GOSUB 2670
690 REM LET'S SEE IF THERE IS AN ECLIPSE ON THIS DATE
700 TE=ABS(SIN(FM))
710 REM IF NO ECLIPSE, PRINT MESSAGE AND TRY NEXT LUNATION
720 IF TE>.36 THEN GOSUB 2300 ELSE 770
730 K=K+BF
740 GOTO 390
750 REM ECLIPSE IS NOW VERY LIKELY
760 REM CALCULATE VARIOUS LUNAR RADII
770 S1=5.19595-.0048*COS(SM)+.002*COS(2*SM)
780 S1=S1-.3283*COS(MM)-.006*COS(SM+MM)
790 S1=S1+.0041*COS(SM-MM)
800 C1=.207*SIN(SM)+.0024*SIN(2*SM)-.039*SIN(MM)
810 C1=C1+.0115*SIN(2*MM)-.0073*SIN(SM+MM)
820 C1=C1-.0067*SIN(SM-MM)+.0117*SIN(2*FM)
830 REM CALC LEAST DISTANCE OF SHADOW AXIS (GY)
840 GY=S1*SIN(FM)+C1*COS(FM)
850 G1=ABS(GY)
860 REM CALC RADIUS OF UMBRAL CONE (UM)
870 MU=.0059+.0046*COS(SM)-.0182*COS(MM)
880 MU=MU+.0004*COS(2*MM)-.0005*COS(SM+MM)
890 REM CALC SEMIDURATIONS OF ECLIPSE PHASES
900 REM UR(0-2) ARE FOR LUNAR, UR(3&4) ARE FOR SOLAR
910 NT=.5458+.04*COS(MM)
920 UR(0)=1.5572+MU:UR(1)=1.0129-MU:UR(2)=.4679-MU
930 UR(3)=1.572+MU:UR(4)=1.026-MU
940 REM CALC ECLIPSE MAGNITUDES (LUNAR & SOLAR)
950 REM MG=SOLAR, PM=PENUMBRAL, UM=LUNAR UMBRAL
960 MG=(1.5432+MU-G1)/(.546+2*MU)
970 PM=(1.5572+MU-G1)/.545
980 UM=(1.0129-MU-G1)/.545
990 REM CALC NODE OF ECLIPSE (ASCENDING/DESCENDING)
1000 ND=COS(FM)
1010 IF ND<0 THEN ND$="Descending" ELSE ND$="Ascending"
1020 REM SEE IF MOON PASSES N OR S OF EARTHS SHADOW AXIS
1030 IF GY<0 THEN NS$="South" ELSE NS$="North"
1040 REM SEE IF ECLIPSE IS LUNAR
1050 IF (LS$="L") AND (PM>=0) THEN GOSUB 1580 ELSE 1090
1060 GOSUB 1960
1070 GOTO 1230
1080 REM 2ND CHECK FOR LUNAR ECLIPSE
1090 IF (LS$="L") AND (PM<0) THEN GOSUB 2300:GOTO 1310
1100 REM CALC CIRCUMSTANCES OF SOLAR ECLIPSES
1110 REM 2ND CHECK TO SEE IF THERE IS A SOLAR ECLIPSE
1120 IF G1>1.5432+MU THEN GOSUB 2300:GOTO 1310
1130 REM CHECK TO SEE IF ECLIPSE CENTRAL
1140 IF G1<.9972 THEN II%=0 ELSE 1190
1150 GOSUB 1350
1160 GOSUB 1960
1170 GOTO 1230
1180 REM CHECK TO SEE IF ECLIPSE IS NON-CENTRAL
1190 T2=1.5432+MU
1200 IF (G1>.9972) AND (G1<T2) THEN II%=1 ELSE 1320
1210 GOSUB 1470
1220 GOSUB 1960
1230 PRINT
1240 INPUT"<C>ontinue, <E>nd program, <M>enu";D$
1250 D$=CHR$(ASC(D$) AND 223)
1260 IF D$="C" THEN 1310
1270 IF D$="E" THEN 1320
1280 IF D$="M" THEN 230
1290 GOTO 1230
1300 REM INCREASE K TO NEXT LUNATION & CONTINUE SEARCH
1310 K=K+BF:GOTO 390
1320 END
1330 REM CALCULATE TOTAL/ANNULAR ECLIPSES
1340 REM CHECK II% (0=N/CENTRAL) (1=CENTRAL)
1350 U1=MG
1360 IF II%=1 THEN N%=0 ELSE N%=1
1370 IF MU<0 THEN T1$="Total Solar":GOTO 1440
1380 IF MU>.0047 THEN T1$="Annular Solar":GOTO 1440
1390 REM CHECK TO SEE IF ECLIPSE IS A/T OR ANNULAR
1400 W=ATN(GY/SQR(ABS(-GY*GY+1)))
1410 OM=.00464*COS(W)
1420 IF MU<OM THEN T1$="Annular/Total Solar"
1430 IF MU>=OM THEN T1%="Annular Solar"
1440 SC%=3:GOSUB 1760
1450 RETURN
1460 REM CALC NON-CENTRAL & PARTIAL SOLAR ECLIPSES
1470 U1=MG
1480 T3=.9972+ABS(MU)
1490 IF (G1>.9972) AND (G1<T3) THEN GOSUB 1350:GOTO 1540
```

Left: The solar corona is often the highlight of a total eclipse of the Sun. Roberta Loeper York captured the corona with this 1/8-second exposure using a 300mm f/5.6 lens on Kodak 5247 film.

Right: The Moon appears ruddy from sunlight passing through Earth's atmosphere in Jack and Carla Gibbons photo of a total lunar eclipse. They used a 12.5-inch f/5 telescope and a 1-minute exposure on hypered Fuji 400.

```
1500 IF G1>T3 THEN T1$="Partial Solar"
1510 N%=0:SC%=3
1520 GOSUB 1760
1530 REM "NC" REPRESENTS NON-CENTRAL
1540 T1$=T1$+" (nc)"
1550 RETURN
1560 REM CALC CIRCUMSTANCES OF LUNAR ECLIPSES
1570 REM UM<0 - PENUMBRAL ECLIPSE
1580 SC%=0
1590 IF UM<0 THEN 1700
1600 IF UM>=1 THEN T1$="Total Lunar" ELSE GOTO 1650
1610 N%=2
1620 U1=UM
1630 GOSUB 1760
1640 GOTO 1730
1650 T1$="Partial Lunar"
1660 N%=1
1670 U1=UM
1680 GOSUB 1760
1690 GOTO 1730
1700 T1$="Penumbral Lunar"
1710 U1=PM
1720 N%=0:GOSUB 1760
1730 RETURN
1740 REM CALC PHASE TIMES IN HRS & MIN.
1750 REM SD(I)=TIMES IN DECIMAL HOURS
1760 FOR I%=0 TO N%
1770 SD(I%)=SQR(UR(I%+SC%)^2-GY^2)/NT
1780 NEXT I%
1790 REM CALC PHASE TIMES IN HRS & MINS.
1800 FOR I%=0 TO N%
1810 GS%=4*I%
1820 TI%(GS%)=INT(((H2-SD(I%))-INT(H2-SD(I%)))*60)
1830 TI%(GS%+1)=INT(H2-SD(I%))
1840 TI%(GS%+2)=INT(((H2+SD(I%))-INT(H2+SD(I%)))*60)
1850 TI%(GS%+3)=INT(H2+SD(I%))
1860 NEXT I%
1870 REM PUT TIMES IN 0-24 HR RANGE
1880 FOR I%=1 TO 11 STEP 2
1890 IF TI%(I%)>=24 THEN TI%(I%)=TI%(I%)-24
1900 IF TI%(I%)<0 THEN TI%(I%)=TI%(I%)+24
1910 NEXT I%
1920 RETURN
1930 REM ************************************************
1940 REM ********* PRINT-ECLIPSE-DATA-SUBROUTINE ********
1950 REM ************************************************
1960 PRINT:PRINT:PRINT
1970 PRINT TAB(20)"Eclipse Event Summary"
1980 PRINT USING"Date of Eclipse      ##/##/####";D1%,D2%,D3%
1990 PRINT"Type of Eclipse            ";T1$
2000 PRINT"Moon is at                 ";ND$;" Node"
2010 IF LS$<>"L" THEN 2030
2020 PRINT"Moon passes                ";NS$;" of Earth's shadow axis"
2030 PRINT USING"Eclipse Magnitude          #.##";U1
2040 PRINT:PRINT TAB(20)"Phase Times of Eclipse"
2050 IF LS$="S" THEN GOSUB 2190 ELSE GOSUB 2080
2060 RETURN
2070 REM PRINT LUNAR ECLIPSE PHASE TIMES
2080 PRINT USING"Moon Enters Penumbra   ##:## ET";TI%(1),TI%(0)
2090 IF N%=0 THEN GOSUB 2270:GOTO 2160
2100 PRINT USING"Moon Enters Umbra      ##:## ET";TI%(5),TI%(4)
2110 IF N%=1 THEN GOSUB 2270:GOTO 2150
2120 PRINT USING"Totality Begins        ##:##.ET";TI%(9),TI%(8)
2130 GOSUB 2270
2140 PRINT USING"Totality Ends          ##:## ET";TI%(11),TI%(10)
2150 PRINT USING"Moon Leaves Umbra      ##:## ET";TI%(7),TI%(6)
2160 PRINT USING"Moon Leaves Penumbra   ##:## ET";TI%(3),TI%(2)
2170 RETURN
2180 REM PRINT SOLAR ECLIPSE PHASE TIMES
2190 PRINT USING"Eclipse Begins           ##:## ET";TI%(1),TI%(0)
2200 IF N%=0 THEN GOSUB 2270:GOTO 2240
2210 PRINT USING"Central Eclipse Begins  ##:## ET";TI%(5),TI%(4)
2220 GOSUB 2270
2230 PRINT USING"Central Eclipse Ends    ##:## ET";TI%(7),TI%(6)
2240 PRINT USING"Eclipse Ends            ##:## ET";TI%(3),TI%(2)
2250 RETURN
2260 REM PRINT TIME OF MAXIMUM ECLIPSE
2270 PRINT USING"Maximum Eclipse         ##:## ET";TI%(13),TI%(14)
2280 RETURN
2290 REM SORRY !, NO ECLIPSE TODAY
2300 PRINT
2310 PRINT USING"There is no Eclipse on ##/##/####";D1%,D2%,D3%
2320 RETURN
2330 REM **************************************************
2340 REM ************* DATA ENTRY SUBROUTINE ************
2350 REM **************************************************
2360 PRINT
2370 INPUT"Enter the Year  :";Y%
2380 INPUT"Enter the Month :";M%
2390 IF M%<1 OR M%>12 THEN 2380
2400 INPUT"Enter the Day   :";D%
2410 IF (D%<1) OR (D%>31) THEN 2400
2420 IF (M%=2) AND (D%>29) THEN 2400
2430 INPUT"Do you want a <L>unar or <S>olar eclipse :";LS$
2440 LS$=CHR$(ASC(LS$) AND 223)
2450 IF (LS$<>"L") AND (LS$<>"S") THEN 2430
2460 INPUT"Search <F>orward or <B>ackward in time   :";BF$
2470 BF$=CHR$(ASC(BF$) AND 223)
2480 IF BF$="F" THEN BF=1:GOTO  2510
2490 IF BF$="B" THEN BF=-1:GOTO 2510
2500 GOTO 2460
2510 RETURN
2520 REM **************************************************
2530 REM *********** DAY-OF-YEAR SUBROUTINE *************
2540 REM **************************************************
2550 LY%=0
2560 A2=Y%/4-INT(Y%/4)
2570 B2=Y%/100-INT(Y%/100)
2580 C2=Y%/400-INT(Y%/400)
2590 IF (A2=0) AND (B2<>0) THEN LY%=1
2600 IF C2=0 THEN LY%=1
2610 IF LY%=0 THEN DO%=INT((275*M%)/9)-2*INT((M%+9)/12)+D%-30
2620 IF LY%=1 THEN DO%=INT((275*M%)/9)-INT((M%+9)/12)+D%-30
2630 RETURN
2640 REM **************************************************
2650 REM ******** JD-TO-CALENDAR DATE SUBROUTINE ********
2660 REM **************************************************
2670 JD=JD+.5
2680 IF JD>=1 THEN JW=JW+1:JD=JD-1
2690 Z=FIX(JW)
2700 F=JD
2710 AL%=FIX((Z-1867216.25#)/36524.25#)
2720 A=Z+1+AL%-FIX(AL%/4)
2730 IF Z<2.29916E+06 THEN A=Z
2740 B=A+1524
2750 C%=FIX((B-122.1)/365.25)
2760 DC=FIX(365.25*C%)
2770 E%=FIX((B-DC)/30.6001)
2780 DA=B-DC-FIX(30.6001*E%)+F
2790 IF E%<13.5 THEN E%=E%-1
2800 IF E%>13.5 THEN E%=E%-13
2810 IF E%>2.5 THEN C%=C%-4716
2820 IF E%<2.5 THEN C%=C%-4715
2830 D2%=FIX(DA)
2840 D1%=E%
2850 D3%=C%
2860 H2=(DA-FIX(DA))*24
2870 TI%(13)=INT(H2)
2880 TI%(14)=INT((H2-FIX(H2))*60)
2890 RETURN
```

Just because the Moon's umbra is on top of you doesn't mean the horizon can't still be sunlit. Jim Manning photographed this effect with a 28mm f/2.8 lens and a 1/30-second exposure on Ektachrome 200 in Siberia during a total solar eclipse.

one and the program loops back to check the next New or Full Moon.

If an eclipse does take place, the program analyzes the geometry of the eclipse to determine the type and circumstances of it. For a solar eclipse this involves whether the eclipse is central (when the Moon's umbra intersects the Earth), or non-central. ECLIPSE then figures out if the eclipse is total, annular, or partial, depending on the radius of the umbral shadow and the distances between Earth and Moon.

Next, the program determines the approximate phase times of the eclipse. Finally, the magnitude of the eclipse is determined, telling us the maximum decimal fraction of the solar diameter covered by the Moon during a partial eclipse for a hypothetical observer located at the center of the Earth. (In a total eclipse this number is superfluous.)

For a lunar eclipse the same basic values are calculated. The eclipse magnitude refers to the fraction of the Moon covered by the Earth's shadow. If the umbral magnitude is greater than one, then the eclipse is total; if it's between zero and one, it is a partial eclipse.

Program Output

Once the calculations are complete, ECLIPSE lists the results. First the date of the eclipse is printed. (If the eclipse spans two days, the date given is the one in which the eclipse reaches maximum). The type of eclipse is displayed. (For a solar eclipse the tag "(nc)" afterward refers to a non-central eclipse.) Whether the eclipse happens when the Moon is near the ascending or descending node of its orbit is then printed, followed by the eclipse magnitude.

For a lunar eclipse the display also tells you whether the Moon passes north or south of Earth's shadow axis so that, in a partial or penumbral eclipse, you can tell which hemisphere of the Moon will be eclipsed. Finally, the times of all the phases are listed.

The user is then asked whether he wants to continue a chronological search, go back to the menu to try another starting date, or quit the program entirely.

Program Notes

ECLIPSE has been extensively tested and has given accurate results. Only one error has been found, when it listed an annular central eclipse as annular non-central. Most of the problems that arise are due to a computer's internal inaccuracy with trigonometric functions, which is to some extent unavoidable. Use double precision variables if your computer has that capability. (In this listing double precision constants are followed by a #.)

The times calculated by ECLIPSE may vary from published values by several minutes. Moreover, the times printed are in Ephemeris Time, which is generally more accurate than Universal Time because it is not based on the Earth's rotation. In the present era the difference between the two times is about one minute, so unless you use the program far into the past or future it is simplest to ignore this small error.

You can also have the output go to the printer by simply changing the PRINT statements to LPRINT. I made extensive use of the PRINTUSING feature available in my BASIC for making the output look nice, but ordinary PRINT statements work just as well, even if the columns don't line up as nicely.

I have found this program to be quite useful. No longer must I search through textbooks or magazines to find out when future eclipses will take place. I can sit at my computer console, type a few keystrokes, and decide if I'll be able to go see it.

— Mark Whiteman

Moon are tilted with respect to one another, different parts of their shadows often strike the other object, producing different types of eclipses. The darkest part of an object's shadow is the umbra, the region where the Sun is completely invisible. The region where part of the Sun is visible is the penumbra.

During a total solar eclipse the umbra of the Moon's shadow strikes Earth, cutting a narrow swath as it moves across Earth's face. The penumbra covers a much larger area surrounding the umbra. Places in the penumbra experience a partial eclipse of the Sun. In rarer circumstances the Moon's elliptical orbit carries it far enough away from Earth that its umbra does not quite reach the surface. This results in an annular eclipse where a thin ring, or annulus, of the Sun is visible around the disk of the Moon.

There are also three kinds of lunar eclipses. In a total lunar eclipse Earth's shadow completely covers the Moon, though sunlight refracted through Earth's atmosphere gives the Moon a reddish orange glow. Because the umbra of Earth's shadow is so much larger than the Moon's, total lunar eclipses last much longer than total solar eclipses.

A partial lunar eclipse results when Earth's umbra covers only a part of the Moon, leaving the rest of the Moon in the penumbral shadow. Finally, a penumbral eclipse is one in which the umbra completely misses the Moon. If seen from the lunar surface, the Sun would appear partially eclipsed by Earth.

The Sun moves along the ecliptic slightly less than twice the ecliptic limit each month, so at least one solar eclipse must occur each eclipse season, and as many as two are possible. If an eclipse season falls in January, there can be as many as five solar eclipses in a calendar year, since the same eclipse season recurs in December. Because the ecliptic limits for a total or annular eclipse are smaller, at most one of these can occur in each eclipse season, so during a calendar year there will be between zero and three.

Penumbral lunar eclipses occur about as frequently as solar eclipses; between two and five are possible each year. The number of umbral eclipses varies between zero and three.

The greatest number of eclipses of both kinds that can occur in one year is seven. This last occurred in 1985 when there were four solar eclipses and three lunar.

If all this sounds confusing, it's because it is. Yet the process of predicting eclipses is straightforward; it's the complexity of the calculations that causes difficulties. By having the computer handle these calculations, I can now, with only a few keystrokes, find the date of any solar or lunar eclipse.

Mark Whiteman is a computer programmer living in Glassboro, New Jersey. His long-time interest in computers and astronomy led him to write the ECLIPSE program.

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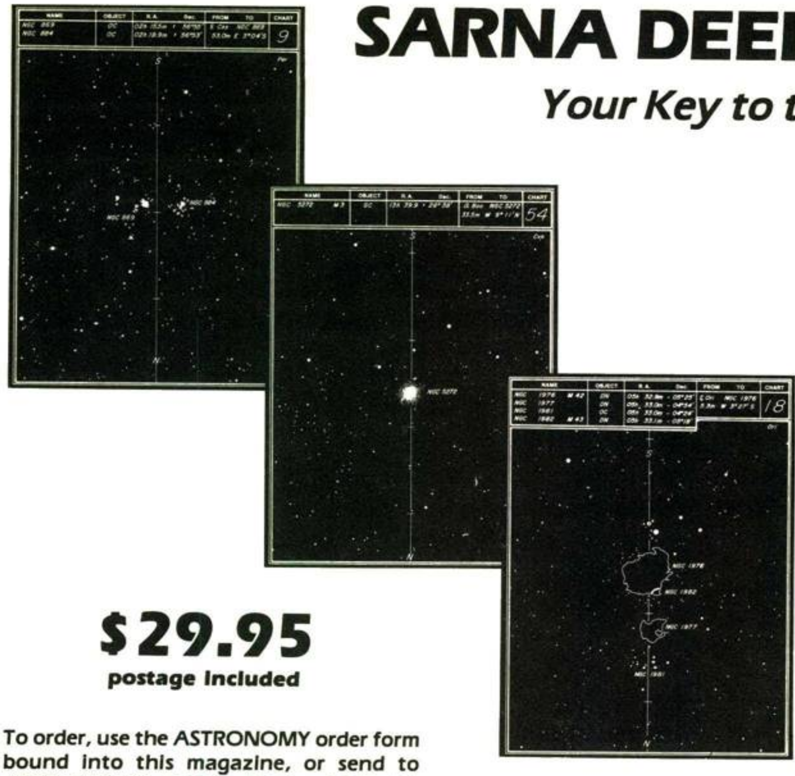

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The Importance of Larger Aperture

Aperture, other things being equal, is the single most important feature of an astronomical telescope. Generally speaking, the larger the aperture, the better the telescope. Thus it is that the most important telescopes in the world today tend to be the largest; that the newest designs for research instruments tend to be ever larger than existing behemoths.

The reason for this fact is quite straightforward. Aperture, usually specified in terms of the diameter of the primary optical element of the particular system, controls: (1) "light-gathering power", (2) resolution, and (3) maximum "usable" magnification. The greater the aperture, the better the telescope will perform in each of these three categories.

Maximum usable magnification, for example, is generally stated to be about 60 power per inch of aperture. Thus, whereas an 8.0in aperture scope is theoretically capable of 480x maximum, a 10.0in scope is potentially capable of 600x. The same holds true for resolution, which is a measure of the ability of an optical system to reproduce fine detail; an 8.0in aperture is theoretically capable of distinguishing features separated by 0.56arcsec, whereas a 10.0in scope can represent separations of 0.45arcsec.

More important than magnification or resolution, however, is "light-gathering power". Light-gathering is what most astronomical telescopes are really all about; they thus make extremely faint or distant astronomical objects visible to our relatively small and insensitive eyes. They might be thought of as light "funnels" which capture, at the large end, much larger quantities of light than our eyes are capable of, and which then "funnel" that light down so that it may be received through the pupils of our eyes (or recorded on photographic film, etc.). Consequently, most of what we currently know about the larger universe around us has been learned, during the past hundred or so years, almost exclusively by means of astronomical telescopes of ever larger and larger apertures.

Unlike magnification and resolution however, which are "direct" (linear) functions of aperture, light-gathering is a function of the "area" of the aperture, and the area of an aperture is a "geometric" function. That is to say that as aperture (diameter) is increased, light-gathering "area" increases "faster". Thus, a doubling of aperture will increase light-gathering area by a factor of four. This "geometric" relationship is not intuitively obvious to many people, but should be carefully considered because it leads to a rather surprising result, i.e., seemingly trivial increases in aperture (diameter) lead to rather large increases in area, and thus in the ability of a telescope to display faint or distant objects.

Thus a 10.0in scope, which has only 25% more aperture than an 8.0in scope, has 56% more light-gathering ability, and can therefore display objects much fainter or further away than a superficial consideration of the 1.0in increase in aperture-radius might lead one to believe.

For the amateur astronomer, of course, there are severe real-world constraints, primarily cost, transportability, and ease of use, which put extremely large aperture scopes beyond reach, or even desire. Meade's 2120 GEM (shown above right), a 10.0in aperture Schmidt-Cassegrain, represents, in our judgment, the best combination of large aperture, sophistication, versatility, transportability, ease of use and usefulness, and reasonable cost, available today. There is simply nothing else like it available at anywhere near the price. Meade is to be congratulated on having made such a large-aperture telescope available, and we heartily recommend it.

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Meade 2120 GEM Base Model (See Illustration, above right)

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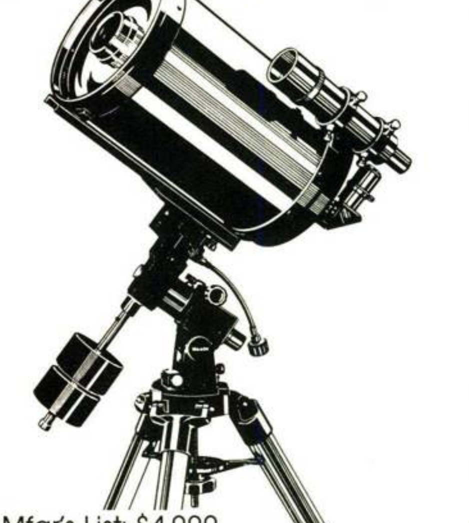

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Are Two Eyes Better Than One?

by Lee Cain

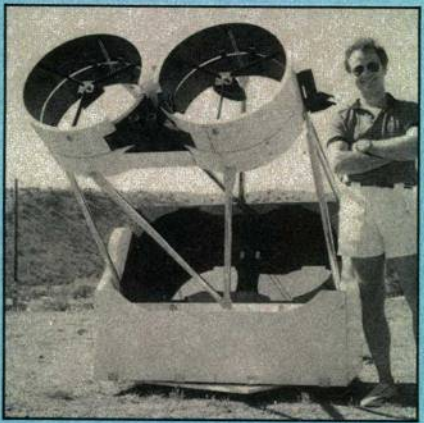
Human beings have two eyes, yet most of us use only one for observing stars through a telescope. What are we missing when we confine ourselves to one-eyed viewing? What might we gain by opening both our eyes to the night sky? Some people claim that the images from two eyes are simply redundant and that one eye is as good as two. Others say the total image looks twice as bright. Actually, the truth lies somewhere in the middle.

Naturally, two-eyed, or binocular, vision is good for seeing depth in the world around us. But this does not apply to the night sky. Astronomical objects are so far away that we can never see them in stereo, except, possibly, in photographs. However, if you doubt the value of binocular vision for stargazers, simply go outside, look up at the sky, and cover one eye. Very few people see as much with one-eye, or monocular, vision as they can with both eyes open.

Central to understanding the value of binocular vision in astronomy is the concept of the eye as a "noisy" receptor. Try another experiment: Close your eyes and put your hands over them to block all light. You may see some afterimages when you first shut your eyes, but after they fade you'll notice that the view before your eyes is not a smooth, featureless black. I don't know what all that stuff is, but you can see that it isn't an ideal background.

Depending on whether you're dark adapted or not, how tired or excited you are, and your overall state of health, you'll see a mottled, scintillating, or salt-and-pepper background with occasional flashes, lines, and other image "noise" superimposed on it. Jolt your head a little and you'll see even more. Or press lightly on your eyelid and enjoy the light show. In the surreal low-light terrain of deep-sky astronomy, image clutter and noise compete with the unfamiliar "signal" of nebulae, galaxies, and other faint deep-sky objects.

Binocular vision provides the brain with a confirmation of what's real and what is not. By comparing the images from two eyes, the brain is able to recognize objects that are present in the images from both eyes, which it interprets as "real." It also recognizes the unconfirmed background from each eye, assumes that it's internally generated noise, and filters it out. In essence, the "signal-to-noise" ratio is improved when you view with two eyes. The result is that you see fainter images with increased contrast against a darker, smoother, more featureless background.



This home-built 17.5-inch binocular telescope made quite a hit at the 1983 Texas Star Party. At 83x magnification they revealed stunning detail for everyone who tried them under the dark Texas skies. The observer stands facing the telescope mirrors and looks into two eyepieces near the upper end of the tube. Rotating secondary mirror units on the two telescopes allow the observer to set the interocular separation without losing telescope collimation. Author Lee Cain stands beside the binoculars. Photo by Richard Berry.

The gains from binocular vision occur with the unaided eyes, as you can easily see for yourself on any clear night. Most amateur astronomers are familiar with standard hand-held binoculars, such as 7x50s, and with the bigger 10x80s that have recently become so popular. My interest in binocular astronomy led me to build binocular telescopes with apertures of 10 inches, 13 inches, and 17 inches.

Contrast Enhancement

In an article in *Nature* (October 1965, Volume 208), authors Campbell and Green found that binocular vision yields a gain of approximately 40 percent in the visibility of low contrast test objects. They give a mathematical explanation of the binocular advantage: "the standard error of the sum of x independent measurements of a random or noisy process decreases as the square root of x, so an observer using two eyes can detect a square root of 2 lower contrast image." In other words, your ability to see a faint nebula improves with the square root of the number of detectors you use:

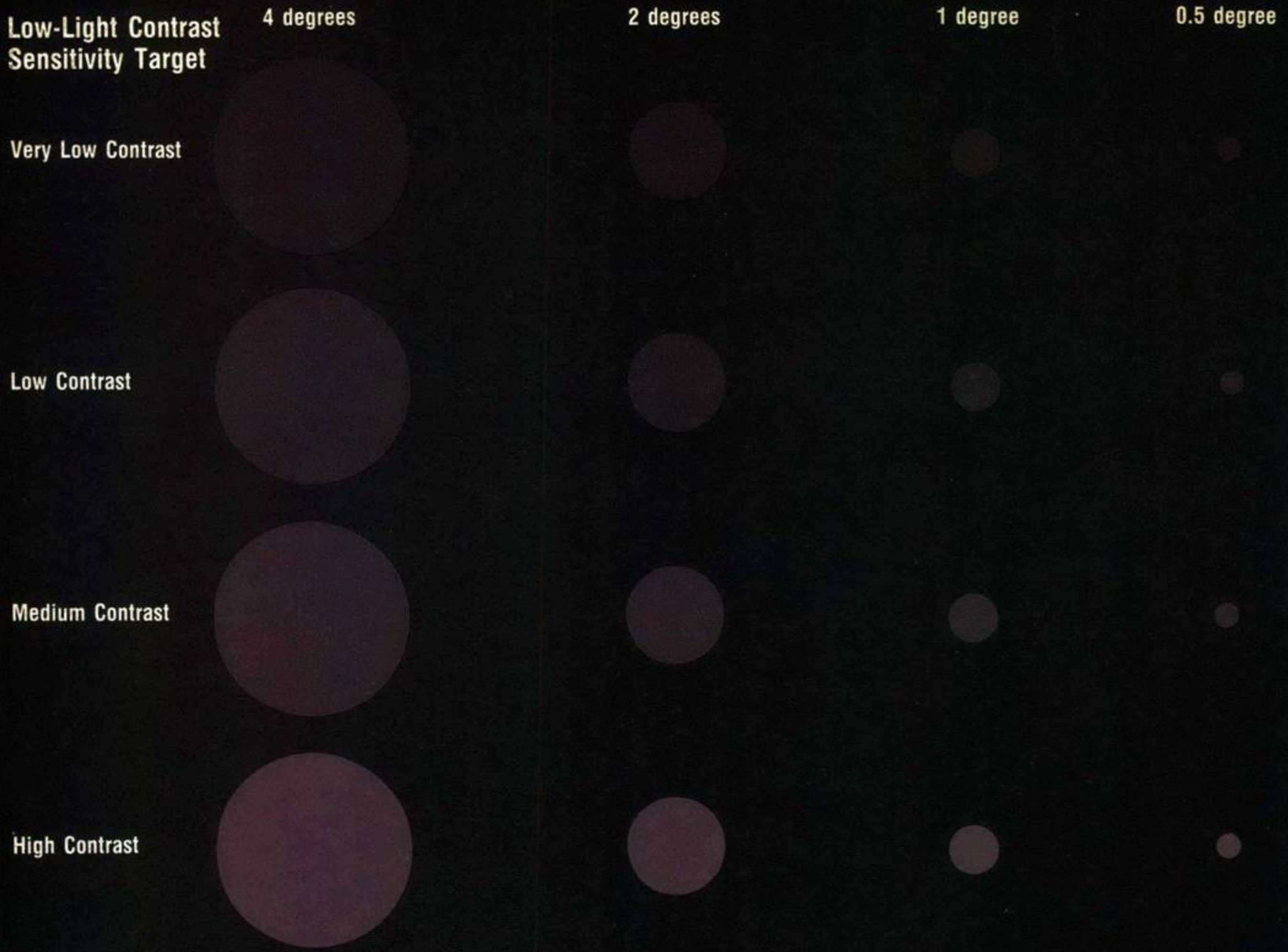
Visibility = SQR(# of eyes)
= SQR(2)
= 1.414

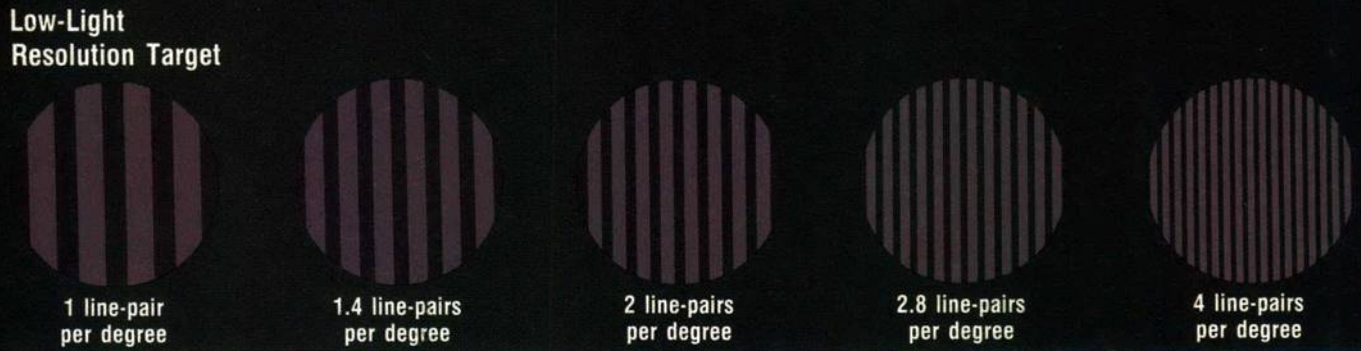
Another way of stating this is that binocular viewing lowers the smallest contrast difference the eye can detect. Image contrast — how well an object stands out against the sky background — is even more important than brightness, as is demonstrated by the fact that nebular filters work. But the binocular advantage doesn't involve selective dimming, as occurs with filters.

Two very different objects that show this advantage best are the Pelican and Horsehead nebulae. With all observing variables in your favor, monocular viewing provides only glimpses of these objects. Using a large binocular telescope, I have observed them directly and continuously.

The test patterns on page 76 allow you to conduct experiments with the binocular advantage indoors under controlled conditions. You will probably be able to see smaller contrast differences with both eyes than you can with only one.

When viewed with large binoculars, the visual impression of large, homogeneous nebulae is one of smoothness. Many observers report that nebulae look grainy


Low-Light Contrast Sensitivity Target
4 degrees
2 degrees
1 degree
0.5 degree
Very Low Contrast
Low Contrast
Medium Contrast
High Contrast


Low-Light Resolution Target
1 line-pair per degree
1.4 line-pairs per degree
2 line-pairs per degree
2.8 line-pairs per degree
4 line-pairs per degree

Top: If you can see the 1-degree object in the Medium Contrast row, the room is too bright; darken it still further. Under dim illumination objects that have low contrast and are small are the most difficult to see. Determine which you can see and which you cannot see with one eye covered. It may be difficult to decide; an object may pop into visibility briefly, then disappear. Does averted vision help you in seeing low-contrast or smaller objects? Which is better for seeing small and low-contrast objects, two eyes or one?

Bottom row: While a low-contrast bar target may not resemble a galaxy's spiral arms, you can still explore the effect binocular viewing has on your ability to detect detail at low light levels. Which is the finest pattern you can see with one eye? With two? Does averted vision help?

How To Use This Page: You will need a room you can darken to the light level of a dark-sky observing site. Start with a dim night light illuminating the room, then progressively shield it until you can barely see at all. With your eyes fully dark-adapted you will not be able to read ordinary type or even headline type. Once the lighting is set, hold the page fourteen inches from your eyes.

with monocular vision. This graininess is the "high gain" noise of the dark-adapted eye, and is just like the graininess of the picture from a video camera on its low-light setting. This graininess is attenuated with the square root of the number of eyes used.

Low-Light Threshold

When observing at the lower threshold of visibility, a 41 percent gain in contrast permits a 41 percent dimmer image to be seen. This is true of both nebulae and stars. For nebulae, this advantage cannot be gained by increasing the aperture of the telescope because this brightens the sky background as well as the image.

Dr. Keith Bowen, an optometrist and amateur astronomer from Colorado, has tested volunteers and found that the faintest light stimulus detectable, using binocular vision, ranges from 25 to 40 percent better than monocular performance. In my own experience, I've found that in the heart of the Virgo Cluster I can see eight galaxies in the field of M-86 with 13.1-inch binoculars, as opposed to only five using either eye alone.

With emission and reflection nebulae, using two eyes darkens and smoothes the appearance of the sky background, making the object more visible. This change appears to stem from the brain's active role in comparing the images from the two eyes. With dark nebulae, binocular viewing seems to darken the nebulae. If a dark nebula is superimposed on a brighter nebulous area, so that contrast of the scene limits the single eye's ability to detect it, the binocular telescope offers a 41 percent advantage.

Limiting Magnitude

Two eyes can see faint stars better than one eye can. As Richard Berry, who used my 17.5-inch binoculars at the 1983 Texas Star Party, stated in an article published in *Telescope Making* #23: "For me, viewing with two eyes adds about one-half magnitude." His estimate is a tad higher than theory predicts. It predicts a change in limiting magnitude due to a 41 percent increase in contrast sensitivity:

$$\begin{aligned}\text{Gain} &= 2.5 \times \log(\text{brightness change}) \\ &= 2.5 \times \log(1.41) \\ &= 0.37\end{aligned}$$

The magnitude gain with two eyes should be 0.37 magnitude. Of course, you could gain 0.37 magnitude by increasing the aperture of your telescope by 19 percent, which would probably cost you considerably less than building a large binocular telescope. So, although binoculars provide an advantage on all objects, if you observe stars at low to moderate magnification, you can get the same contrast and threshold benefits from a modest increase in aperture, such as, for example, trading your 8-inch scope for a 10-inch scope.

Perception of Fine Detail

Dr. Bowen's study reveals that in high-contrast situations a 5 to 10 percent improvement in resolution is seen in binocular vision over monocular vision. This is nice, but it really doesn't justify binoculars for observing planets or double stars since a modest increase in aperture will yield the same improvement.

In low-light situations where seeing detail is important, such as when you are observing planetary nebulae, binoculars display a significant advantage. Campbell and Green found "the binocular improvement [in the perception of fine detail] to be on the order of 40 percent when low contrast targets are used."

Viewing With Binoculars

What do these advantages mean in practical observing? From my own experience and discussions with other observers, here's what I've found.

Globular Clusters. Using a conventional 16-inch telescope, observers often comment that the dense cluster Omega (ω) Centauri seems to writhe with "snakes" running through it. Some people even say it looks like "boiling oatmeal." This is an altogether different phenomenon from atmospheric scintillation. I think it's caused by the brain seeking a pattern in the tenuous stars making up the globular. The view with two eyes seems steadier and you can see deeper into the core.

Dark Nebulae. Jack Marling and Richard Berry both found dark nebulae to be a strong suit of the 17.5-inch binoculars I built. Richard wrote: "As I scanned the binocular across the region of the galactic center, I began, rather modestly, looking for some dark nebulae I'd seen 2 nights earlier [with a 19-inch telescope]. . . . The problem soon became an embarrassment of riches; which of the many dark nebulae visible were the ones I'd seen before? Scanning revealed dozens."

Color Enhancement. Color seems to be enhanced by binocular vision. The subtle rust and rose hues in the outer parts of the Orion Nebula are a little easier to see than they are with a monocular telescope of similar aperture. I can't put any numbers to the difference, however. Color perception is greatly affected by each individual's vision, and maybe a little by imagination, too.

3-D Effect. In the past I've always been careful to point out that there is no observable parallax to celestial objects, but I'm no longer being such a technical fuddy-duddy. I sometimes find myself enjoying the brain's trickery when some things, particularly open clusters, look three-dimensional through binocular telescopes.

Presence. The strongest impression I get using binoculars is visceral and unmeasureable. It is a feeling that I am actually seeing the object, not just a likeness of it. Many inexperienced viewers say they feel like they're looking "through" a window, whereas with a monocular telescope they feel like they're looking "into" the eyepiece at a little picture. Two factors may contribute to this: 1) the brain puts greater confidence in a verified image, and 2) the two images have an apparent size and distance.

Can Monocular Scopes Compete?

Of course they can. People often ask me what size binoculars are the equivalent of a given monocular telescope. I used to say that binocular and monocular telescopes of equal mirror area were roughly equivalent, but the answer is more complex than that. For viewing stars, a monocular telescope with an objective 19 percent larger is the equivalent of a binocular telescope. But with the bright planets a monocular telescope only 10 percent bigger gives the same result. However, for dim extended objects binoculars have a 41 percent advantage that cannot be duplicated with aperture.

How about using a binocular viewer, an optical device that divides one beam of light into two, with a monocular telescope? With a binocular viewer you run into two problems. First, the optical system in most of them can't accommodate the converging cone of light from a fast Newtonian primary mirror, and therefore they are not suitable for deep-sky observing.

More fundamentally, when you split the light for the two eyes, you cut the brightness to each eye to no more than 50 percent of its original brightness, but you recover only 41 percent of the loss due to the integration of the images in the brain. (Actually, only about 30 percent of the original light reaches each eye. The rest is lost in the beamsplitter mirrors in the viewer.) At best, then, this nets out to 71 percent (0.50 x 1.41) of the low light contrast sensitivity you have with the same telescope used as a monocular. Realistically, it's more like 42 percent (0.30 x 1.41), or as good as the monocular view. For many people, though, the comfort of binocular viewing is worth the light loss, especially for bright objects.

What about using a binocular viewer on a larger monocular telescope? For deep-sky viewing it could be done with a monocular telescope 41 to 60 percent larger in aperture, depending on the efficiency of the beamsplitter coatings in the binocular viewer. However, true binoculars have a fundamental advantage. Simply put, binoculars put the largest objective area to work at the lowest magnification — the classic formula for deep-sky observing.

Where Can I Buy Big Binoculars?

You can't. You have to make them. From time to time over the years amateur telescope builders have built large binocular telescopes. But they aren't easy, and I speak from personal experience, having made quite a few myself. I won't bore you with the construction details here since articles about these instruments have already appeared in *Telescope Making* #20 ("Designing and Constructing a 13" Dobsonian Binocular"), #23 ("Fantastic Observing With Giant Binox"), and #24 ("Lee Cain's *Trans*portable Dobsonian Binocular").

For a short time Lumicon manufactured 10-inch binoculars, but they weren't a commercially viable product and have been dropped. Binoculars would be a good project for an astronomy club. With enough people you can divide the work and costs more ways, and you have a larger pool of skills to draw on.

In summary, if you observe only stars and bright planets, save your money and get a slightly larger monocular telescope. But if your interest is galaxies or nebulae and you have the time, energy, and skills to construct one, then large binoculars offer significant and unique advantages.

Amateur astronomer Lee Cain is vice president of the Houston Astronomical Society, and this year led a Halley's Comet tour to South America. He is the builder of over a dozen telescopes, most of them binoculars. "I'm always trying," he has said, "to sell the idea of two-eyed viewing." Lee writes business computer software for a living.

AstroNews

High-Tech Telescope Receives Federal Grant

A 3.5-meter telescope capable of fully remote controlled operation and rapid instrument changes has received a $3.74 million grant from the National Science Foundation. The new telescope will begin operation on Apache Point in southeastern New Mexico's Sacramento Mountains in 1988.

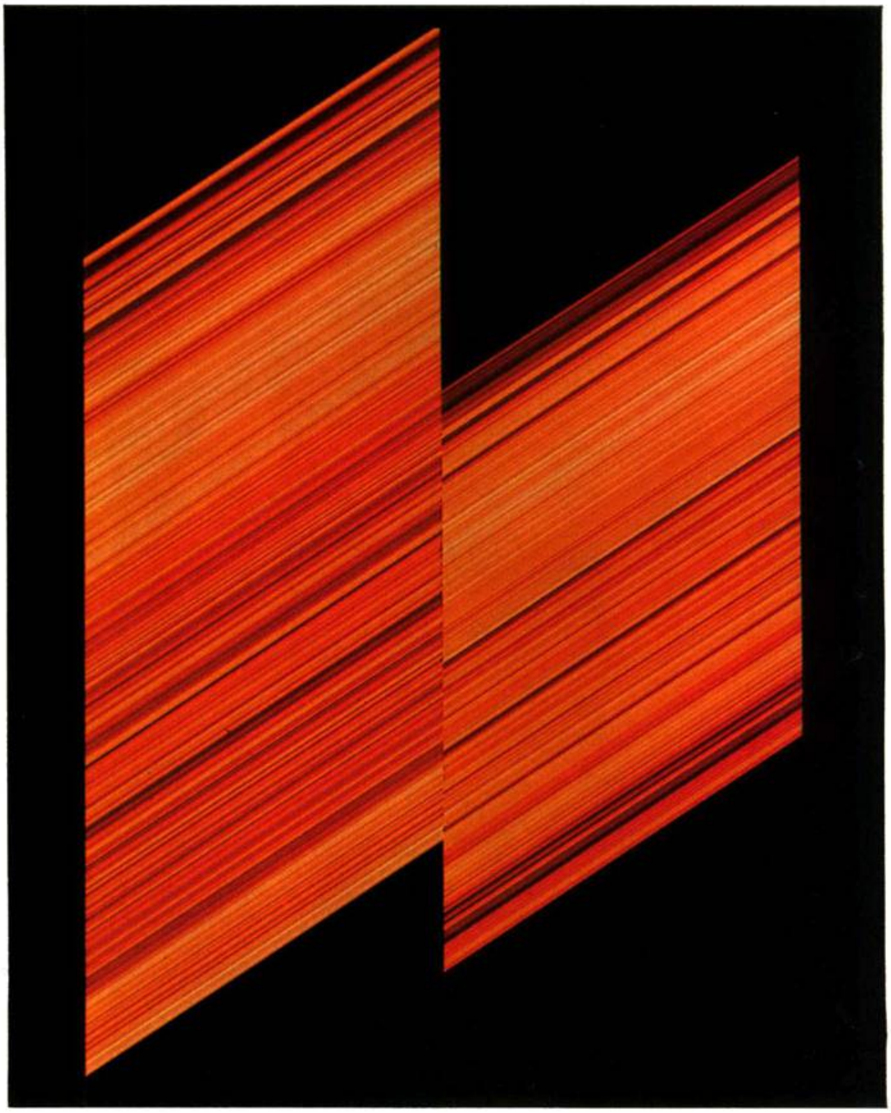
The Astrophysical Research Consortium, a group of five universities, will manage the $10 million facility, which is now under construction. The consortium members are the University of Chicago, the University of Washington, Princeton University, Washington State University, and New Mexico State University.

"Because of its unique design, its size, and the quality of the observing site, this telescope will provide higher performance for many astronomical problems than any other," said Donald York, director of the new observatory and professor of astronomy and astrophysics at the University of Chicago.

The telescope, which will be capable of making observations in both visible and infrared light, will be able to respond quickly to short-lived events such as supernovae because of its permanently mounted instruments. The many hours normally required to change instruments will be saved, making the observing process much more efficient, according to York.

A new light-weight mirror will make the telescope cost efficient, too. The project will cost less than one-third as much as a conventional telescope of the same size due to this new type of mirror. The mirror is a prototype of the kind that will be used in several large telescopes currently planned for the 1990s.

The new facility, with its remote operating capability, will also have unique educational uses. Plans are underway to send images from the telescope directly to video monitors in Chicago's Adler Planetarium and, hopefully, other science museums around the country.



These two computer-enhanced sections of Uranus' epsilon ring were created from data from Voyager 2's photopolarimeter, which measured the amount of light coming from the star Sigma (σ) Sagittarii as it passed behind the rings. The false-color image shows areas containing more material as yellow and areas containing less as dark red. The epsilon ring varies in width as it orbits the planet. The widths of these sections are 31 kilometers and 22 kilometers. The lack of dust- to smoke-sized particles within the rings has prompted speculation that some process may be sweeping dust from the rings, implying that the ring system may be quite young. NASA/JPL photograph.

"Ring Rain" Falling on Saturn

Saturn's atmosphere, unlike Jupiter's, presents more subtle features to telescopes and passing spacecraft because its convective activity is blanketed by a high-altitude haze of ammonia cirrus clouds. However, Voyager images did show several dark bands crossing Saturn's atmosphere in both hemispheres. According to a new atmospheric model, these bands may be regions swept clean of haze by water droplets precipitating from Saturn's rings.

In the August 1986 issue of *Geophysical Review Letters*, John E. P. Connerney of NASA's Goddard Space Flight Center in Greenbelt, Maryland, outlines his model, which credits the rings with an active role in the planet's meteorology.

The process begins when ice particles in the rings collide with each other or with meteoroids, breaking off tiny pieces of ice only a millionth of an inch in size. Such collisions leave the splintered particles electrically charged. Connerney states that if these particles have a low enough mass, their charges cause them to be captured by the field lines of Saturn's magnetic field (which encompasses the ring system) and carried down into the atmosphere in either the northern or southern hemisphere, depending on the charge of the particle. In the upper atmosphere, haze particles act as nuclei about which these ice bits collect. When a sufficient number of haze particles have gathered, they become heavy enough to fall down to lower altitudes.

Crucial to Connerney's model is the fact that the axis of Saturn's magnetic field is nearly parallel to the planet's axis of rotation. Hence, field lines originating from particular latitudes in one hemisphere will pass through specific places in the rings, then re-enter the planet at given latitudes in the opposite hemisphere. This allows certain regions of Saturn's rings to be linked to areas of banding in the planet's atmosphere.

For example, if a field line intersects a specific location in the B ring, charged, low-mass ice particles in that ring will be carried to a specific latitude on the planet. Connerney cites two dark bands in Saturn's northern hemisphere that may be derived from B-ring ice particles.

This "ring rain mechanism" is likely to be found only on Saturn, says Connerney, because of the unique, near-exact alignment of the planet's magnetic field with its rotational axis, and also because the rings are composed mostly of water ice.

Unexpected Rapid Motion Found in Galaxy Clusters

Astronomers have found evidence that the expansion of the universe is not as smooth as they previously thought. The high speeds at which clusters of galaxies move through space — about 1,600 kilo-

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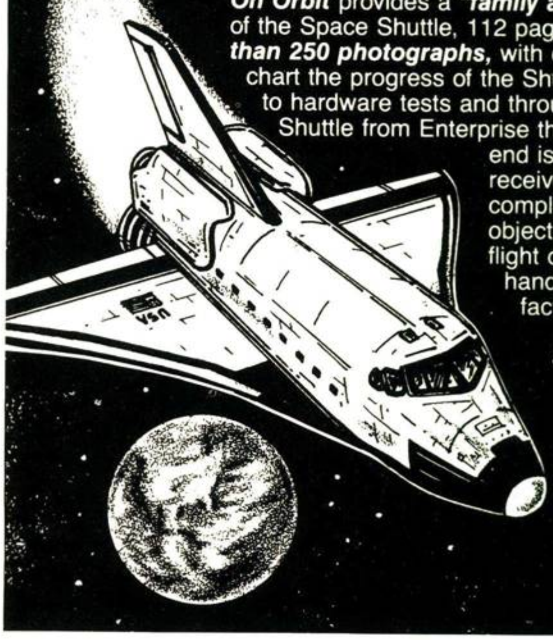

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meters per second relative to the overall smooth expansion of the universe — may indicate the presence of a large amount of unseen matter in the universe.

Researchers Neta Bahcall of the Space Telescope Science Institute in Baltimore, Raymond Soneira of the Institute for Advanced Study at Princeton, and William Burgett, a doctoral student at Johns Hopkins University, detected these extremely high speeds by studying the distribution of clusters of galaxies — in some cases superclusters extending over 300 megaparsecs in length — to a distance of 300 megaparsecs.

Their investigations revealed that the distances between the clusters of galaxies are greater along our line of sight than across our field of view. Although this effect is usually explained as excess motion of the astronomical objects (in this case motion away from the observer), the investigators also suggest that the effect may be due to very large structures, such as gigantic "bubbles" or cells of matter, that are elongated because of the high velocity.

"The surprising high-speed motion within these superclusters of galaxies may indicate the very strong gravitational attraction of a vast mass pulling on systems within the superclusters," Bahcall says. "This would suggest, in turn, that these large structures contain much more matter than previously anticipated, increasing the estimated mass density of the universe."

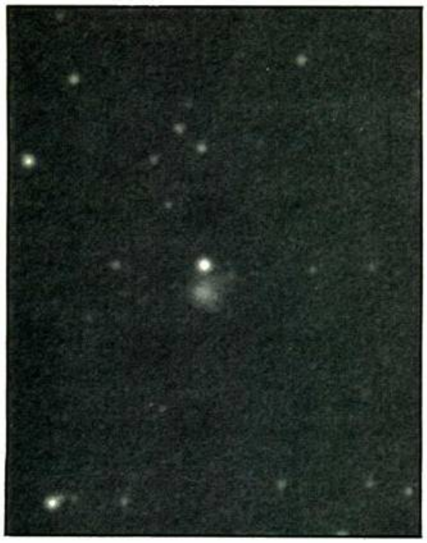
"Alternatively," adds Bahcall, "the motion may be caused by gigantic explosions in the universe after the Big Bang but still early in time." Such explosions have been attributed to the formation of the "soap bubble" structure of the universe (see, "A Bubbling Universe?", AstroNews, May 1986).

In either case, the rapid motions may change our view of the dynamics of the universe. According to Bahcall, "The smooth expansion of the universe on large scales may not be so smooth after all."

Comet Wilson to Be Bright Next Year

On August 5, 1986, a student at Caltech named Christine Wilson discovered a new comet. Wilson found the diffuse object on a plate she made while working on the new Palomar Sky Survey. She communicated her finding to Brian Marsden of the Smithsonian Astrophysical Observatory's Central Bureau for Astronomical Telegrams, who notified observatories of the new comet, named Wilson (1986l).

Wilson originally estimated the comet's magnitude at 7.5, but other observers confirmed that it actually shone around magnitude 10.5. Marsden, upon calculating the comet's orbit, had some encouraging news for the discoverer: Comet Wilson should reach 3rd magnitude and develop a bright tail by April 22, 1987, when it will pass within 1.2 astronomical



Newly discovered Comet Wilson was in Pegasus, glowing softly at magnitude 10.5, two days after its discovery. Photo by Jack Newton.

units from the Sun and just 0.7 AU from Earth.

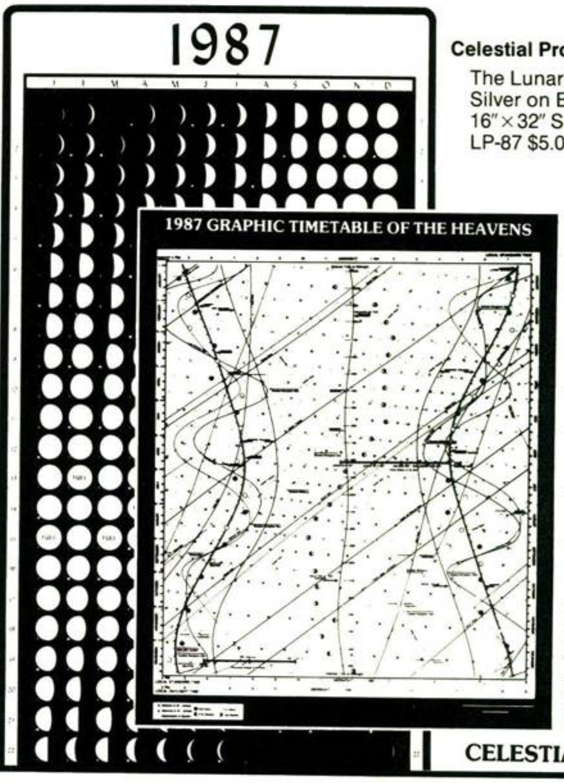
Northern Hemisphere viewers may get their best view of Wilson around April 1 and May 20, 1987, on either side of perihelion, when the comet should glow at about 5th magnitude. At its brightest, which will be a little fainter than Halley's Comet, Comet Wilson will lie deep in the southern sky at −70° declination.

Newly Discovered Quasar Is Most Distant Object In The Universe

A team of American and British astronomers has discovered a quasar with the largest known redshift, making it the most distant object yet discovered in the universe.

The quasar, designated 1208+1011, has a redshift of 3.80, which surpasses the previous record of 3.78 for the quasar PKS 2000−330. This redshift corresponds to an object that is about 90 percent of the way to the edge of the universe.

The discovery is due in large part to a new survey method that is particularly well-suited to finding objects with high redshifts. (Such redshifts are the result of a Doppler shift caused by their great speed of recession.) In previous quasar surveys astronomers have used photographic plates that do not record light with a wavelength longer than about 5200 Angstroms. Because the most dominant emission line in quasar spectra, the Lyman-alpha line of hydrogen, is shifted beyond this cutoff in objects with a redshift greater than about 3.3, such distant objects are difficult to detect with traditional photographic plates. The new survey uses plates that are more sensitive in the red end of the spectrum, allowing far more distant objects to be found.



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The astronomers began their search by taking objective prism plates with the United Kingdom Schmidt Telescope in Australia. These wide-angle plates record incoming light after it passes through a prism and is dispersed into its component colors. The resulting plate contains a spectrum of each object and can easily be searched for high-redshift objects. After identifying several of these they chose the one that appeared to have the largest redshift and obtained a detailed spectrum of it with the 5-meter Hale Telescope on Palomar Mountain. The researchers then measured the redshift precisely and confirmed their earlier suspicions.

The astronomers believe this technique holds great promise for the future. In addition to 1208+1011, four other quasars with a redshift greater than 3.5 were found on the new survey, more than doubling the previously known number of very distant quasars. With the new photographic plates, objects with redshifts up to 4.6 should be visible, if they exist.

Cyril Hazard of the University of Pittsburgh, Wallace Sargent and Charles Steidel of the California Institute of Technology, Richard McMahon of Cambridge University, and Alexei Filippenko of the University of California at Berkeley, reported their findings in the July 3 issue of *Nature.*

Interstellar Gas Falling Into a Black Hole

Analysis of measurements made with the spectrograph carried aboard the International Ultraviolet Explorer (IUE) satellite show the first strong evidence of interstellar gas falling into a black hole. The measurements were analyzed by Martin Gaskell of Ohio State University. Gaskell asserts that the in-falling gas may power a "feeble quasar" located at the center of the nearest bright Seyfert galaxy, NGC-4151, in Canes Venatici.

Many astronomers believe that the unusually high energy output of a Seyfert galaxy is generated by matter accreting onto a supermassive black hole in the galaxy's nucleus. Although their spectra resemble those of quasars, the nuclei of Seyfert galaxies are much less powerful.

Gaskell studied the changes exhibited in the ultraviolet spectrum of the gas near the center of NGC-4151. The red-shifted parts of the emission lines (a Doppler effect caused by gas moving away from us) exhibited variations in strength that occurred before similar changes were seen in the blue-shifted parts of the emission lines (caused by gas moving toward us). This suggests that the gas nearest to us is receding and the gas further away is approaching, implying that material is in-flowing under the influence of a strong gravitational pull. From this, Gaskell calculates that the mass of the black hole is about 60 solar masses.

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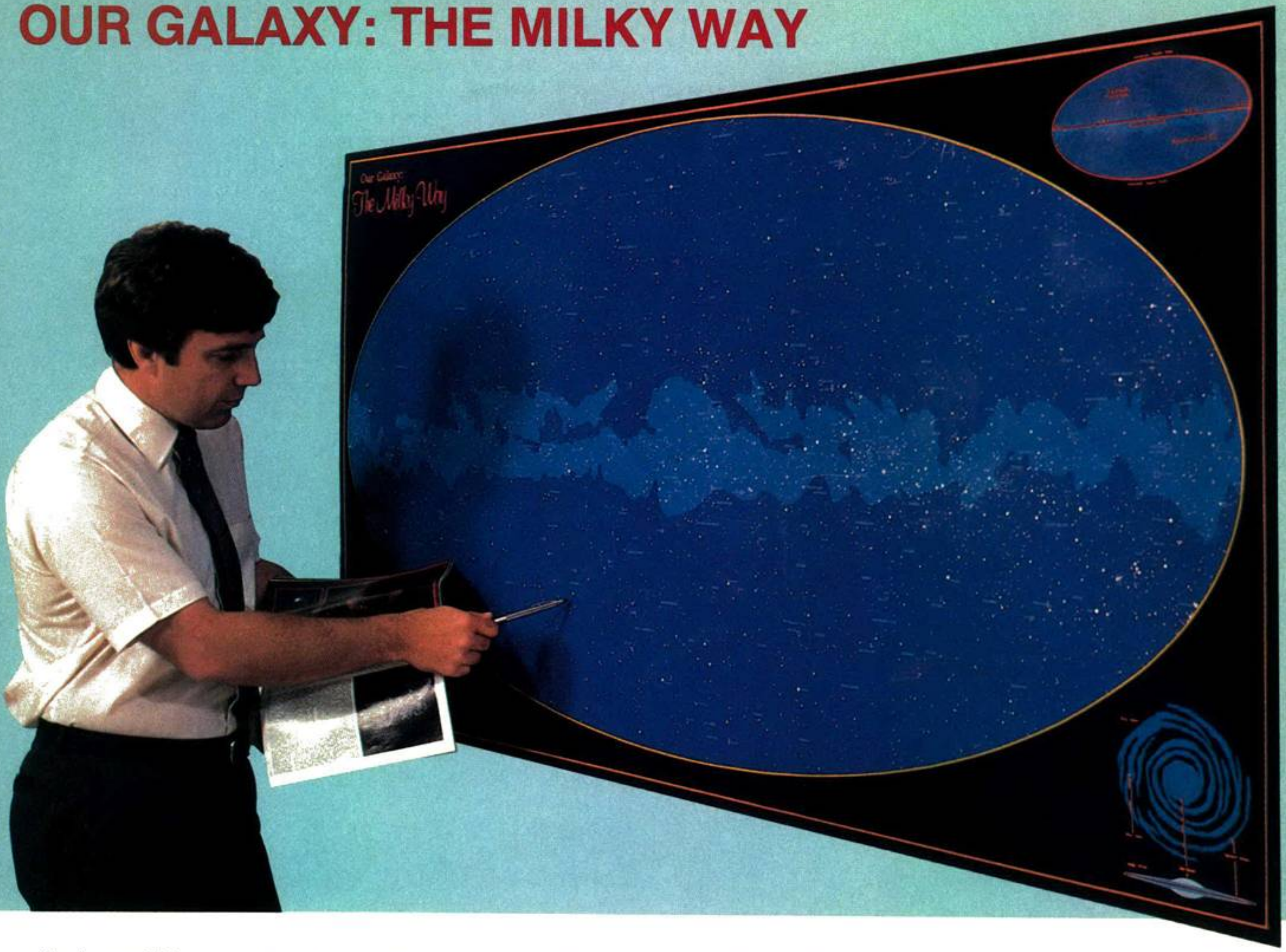

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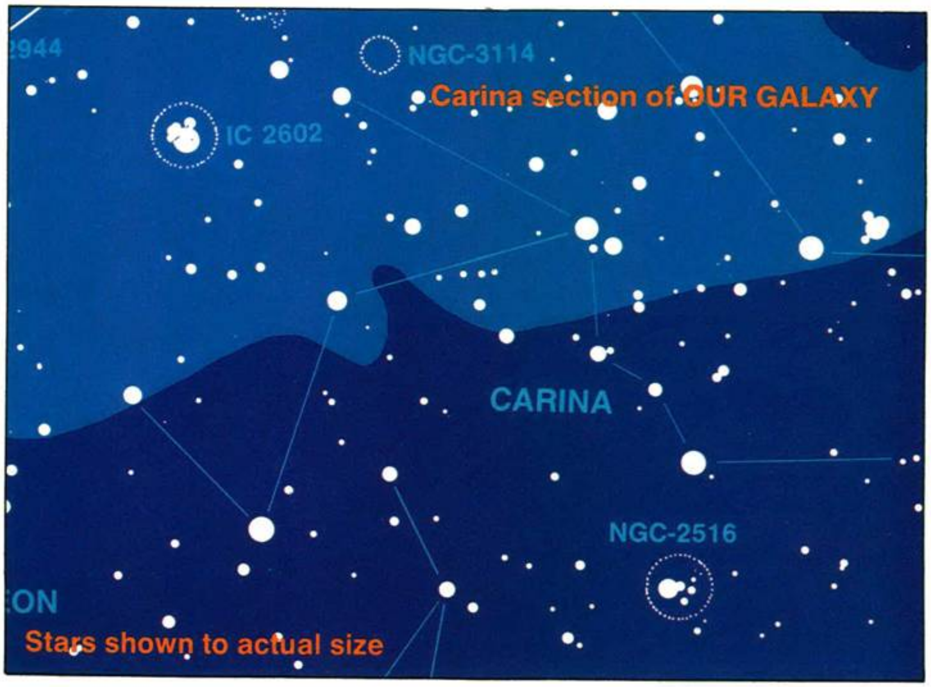
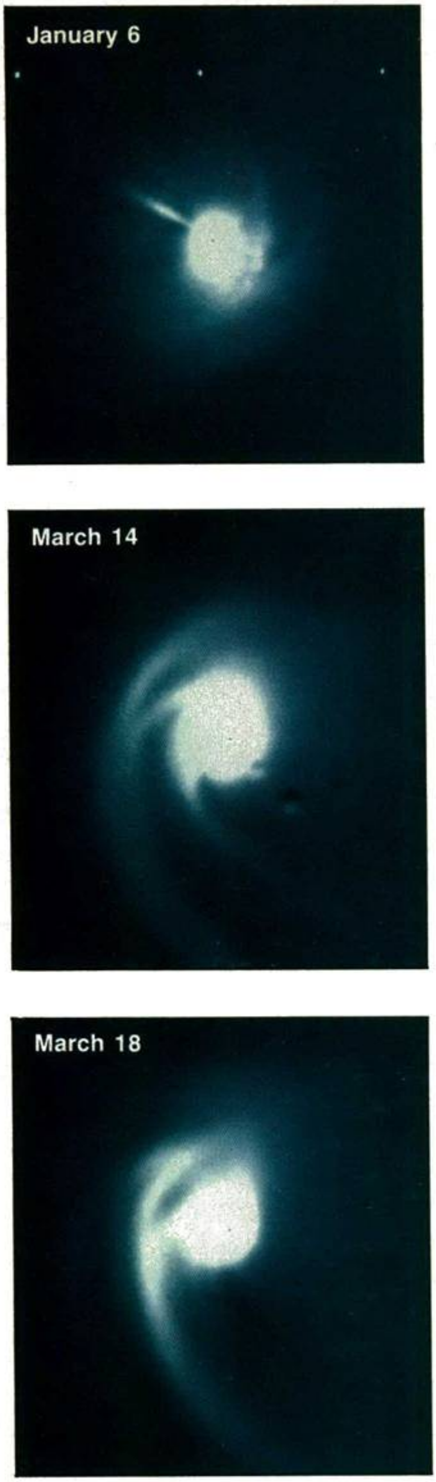


Carina section of OUR GALAXY

Stars shown to actual size



Jet activity in Comet Halley is clearly shown in these high-resolution, computer-enhanced images obtained for the Near-Nucleus Studies Net of the International Halley Watch. The images were taken with a CCD camera and a red filter to enhance the dust component of Halley's light. The January 6 image, taken by Stephen Larson and David Levy of the University of Arizona with the 61-inch Catalina reflector on Mount Lemmon, shows a developing tailward jet, the first detected in Halley at this apparition. The March images were taken by Santiago Tapia of the University of Arizona and Matt Senay of the University of the Orange Free State with the 60-inch reflector at Boyden Observatory in South Africa.

When Galaxies Collide

Recent observations have confirmed that an irregularly shaped galaxy possessing characteristics of both an elliptical and a spiral galaxy is actually a combination of the two caught in the process of colliding. Gerard Gilmore of the University of Cambridge and Martin Shaw of the University of Edinburgh reported their findings in the June 19, 1986, issue of *Nature*.

The galaxy was originally identified with a bright, compact radio source known both as PKS 1345+125 and 4C 12.50. The source varies in output by 30 percent on a timescale of about 4.5 years.

In 1977 the radio source was identified with an unusual 17th-magnitude galaxy at the center of a cluster of galaxies in the constellation Bootes. Different observations led to conflicting pictures of the object. For example, its optical spectrum shows very broad emission lines, indicating that the gas within the galaxy is moving at high speeds, although other characteristics in the spectrum were deemed more significant and led to its classification as a narrow-line radio galaxy. On the other hand, its optical appearance resembles a lenticular (S0) galaxy.

In order to sort out the ambiguities, Gilmore and Shaw decided to study the object in detail. Their initial observations on the 3.9-meter Anglo-Australian telescope showed that the nucleus of the galaxy actually has two components separated by a mere 1.8 arcseconds. The eastern nucleus coincides with the radio source and is brighter in red light than in blue. The western nucleus is much bluer and seems to coincide with an infrared point source discovered by the Infrared Astronomical Satellite.

The most recent observations consist of detailed optical spectra of both nuclei. These were obtained with the 2.5-meter Isaac Newton telescope on a night of exceptional seeing at La Palma.

The picture that emerges is of a violent galactic collision. The larger galaxy is a giant elliptical galaxy associated with the eastern nucleus. The radio-quiet western nucleus belongs to a class of active spiral galaxies known as Seyfert galaxies. The collision has stripped the Seyfert of its stars and interstellar material while fueling the nuclear engine at its core. Calculations show that this engine may well be a supermassive black hole of about 10 million solar masses.

The researchers suggest that the unusual appearance of the galaxy indicates that the collision has been relatively recent. After an interaction such as this, the galaxy's visual appearance should return to normal in a mere 10 to 100 million years, making us fortunate to be able to study this violent event.

ASTRONOMY
AstroCalendar

October 16-18
Rocky Mountain/Great Plains Planetarium Associations Joint Meeting, McDonnell Star Theater, St. Louis, Missouri. Contact: Laura Kyro, St. Louis Science Center, 5050 Oakland Blvd., St. Louis, MO 63110. Phone (314) 289-4456.

October 17-19
Midwest Space Development Conference, Lorain, Ohio. Contact: Jim Wood, Conference Coordinator, 2720 West 40 Street, Lorain, OH 44053. Phone (216) 282-6329.

October 18
Cretaceous-Tertiary Boundary Mass Extinctions conference (dinosaur extinction theories), LaPorte, Indiana, 9 a.m. to 4 p.m. Contact: Sherman P. Kanagy, Purdue University North Central. Phone (219) 785-2541, extension 254.

October 24-26
8th Annual Astronomy Jamboree, Custer Institute, Southold, Long Island, New York. Contact: Tom Carey, Vanderbilt Planetarium, Centerport, NY 11721. Phone (516) 757-7502.

October 25
Telescope Users' Clinic, Whittier College, Whittier, California. Contact: Bob Ferguson, Western Observatorium, 13215 E. Penn St., Suite 411, Whittier, CA 90602. Phone (818) 795-4181.

October 31-November 2
Deep South Regional Stargaze, Percy Quin State Park, McComb, Mississippi. Contact: Frank W. Loflin II, ALCOR, Jackson Astronomical Association, 280 W. Lorenz Blvd., Jackson, MS 39213. Phone (601) 982-2388 days or (601) 856-3636 evenings.

January 4-8, 1987
169th Meeting of the American Astronomical Society (professional meeting sponsored by Mount Wilson Observatory and Caltech), Pasadena, California. Contact: AAS, 1816 Jefferson Pl. NW, Washington, DC 20036.

January 29-February 1
Third Annual Winter Star Party, (sponsored by the Southern Cross Astronomical Society), Everglades National Park, Mahogany Hammock site, Florida. Contact: Tippy D'Auria, 1050 N.W. 145 St., Miami, FL 33168. Phone: (305) 685-6001.

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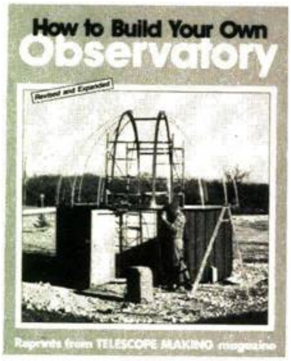

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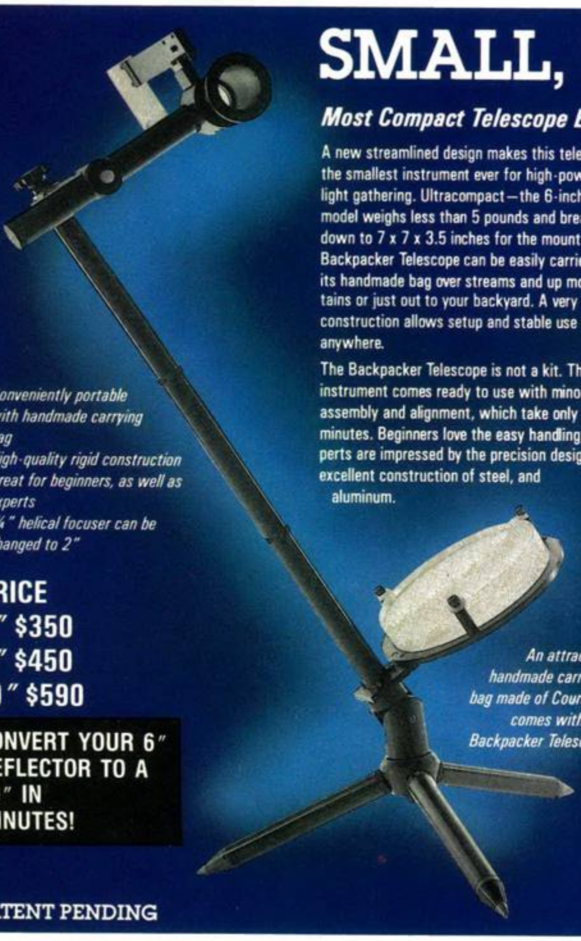

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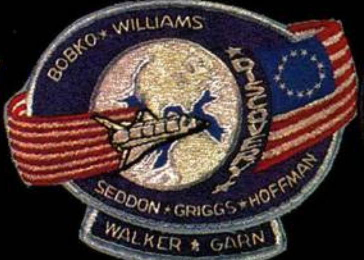
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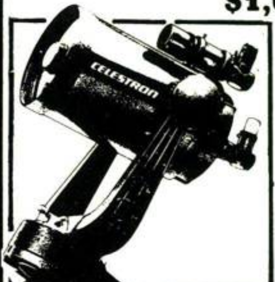

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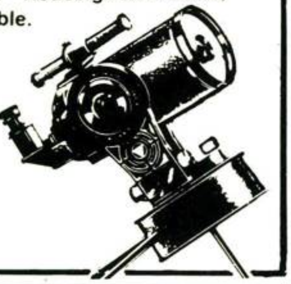

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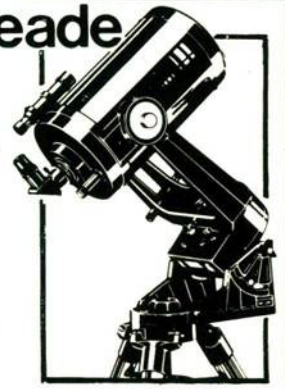

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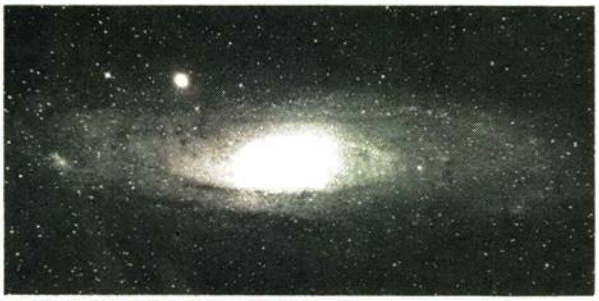

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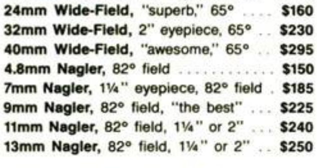

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55mm 2" Plossl, widest possible field	**$190**
15mm Wide-Field, 1¼" eyepiece, 65°	**$130**
19mm Wide-Field, 1¼" eyepiece, 85°	**$145**
24mm Wide-Field, "superb," 65°	**$160**
32mm Wide-Field, 2" eyepiece, 65°	**$230**
40mm Wide-Field, "awesome," 65°	**$295**
4.8mm Nagler, 82° field	**$150**
7mm Nagler, 1¼" eyepiece, 82° field	**$185**
9mm Nagler, 82° field, "the best"	**$225**
11mm Nagler, 82° field, 1¼" or 2"	**$240**
13mm Nagler, 82° field, 1¼" or 2"	**$250**

NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 3.1" enhanced silver diagonal mirrors & 2" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" . **$29.95** 1.52" . **$34.50** 1.83" . **$39.50**
2.14" . **$47.50** 2.60" . **$59.50** 3.10" . **$79.50**
4.25 . **$129.50**

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$79.50**
2" (1.83" mirror)(see photo above)	**$145.00**

LUMICON FILTERS STOP LIGHT POLLUTION

UHC Filter™

ULTRA HIGH CONTRAST

The LUMICON UHC FILTER is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm.

"I CAN SEE THE VEIL NEBULA!"
Rich Zepernick saw the Veil Nebula for the very first time with a LUMICON UHC Filter. He stated, "*It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters.*"
Zepernick, Cresskill, NJ

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 80-95%.

	Standard	**Premium***
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces		**$79.50**
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS		**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$99.50**	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		**$299.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$79.50**	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$159.50**	**$199.50**
Set of Both 1¼" **DEEP-SKY** and **UHC Filters** (Save 11%)		**$159.50**
1¼" H-BETA Line Filter 9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae)		**$89.50**
48mm "Horsehead Nebula" H-BETA Line Filter		**$189.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines		**1¼" $99.50, 48mm $199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm		**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece		**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece		**$20.00**

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

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LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

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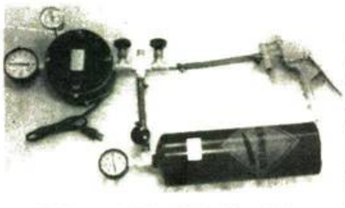

MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

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All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X eaiser guide-star selection, use 48mm filters, 360° camera rotation, large prisms fo bright.guide-starts. *Specify Camera and Telescope type.*
U.S. Patent # 4,448,500

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Full aperture. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$79.50**
Illuminated reticle eyepiece system	**$79.50**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**
CASSEGRAIN EASY-GUIDER **$225.00**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER	**$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)	**add $99.95**
Hasselblad adapter	**$195.00**

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1. **Illuminated reticle eyepiece** ... $79.50
Lumicon 12mm eyepiece system has adjustible L.E.D illumiation, dual crosslines, battery pack.
2. Cable release for long exposures . **$9.95**

3. **LUMICON Quartz Drive Corrector $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.

Declination motor (state telescope) .. **$60**
NEW Deluxe Digital Qtz. Drive Correc. **$298**

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LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

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VR200, fine grain color negs	12	**$9.95**
3M 1000, fastest slide film	20	**$12.95**
Ektachrome 200, fine grain slide	24	**$12.95**
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MEADE 2120/LX3 w/MCSO $2690

NEW! 2080/GEM 8" f/10 w/equatorial mt. ($2100 list)	**$1150**
Multi-coated silvered optics, boost trans. 18%	**add $149**
#36 dual-axis drive corrector control box ($150 list)	**add $99**
#38 declination motor & clutch ($150 list)	**add $99**
Dew shield and accessory tray ($140 list)	**add $89**

2080/LX3
$1685
2080/LX3
W/MCSO

NEW! Quartz Drive Meade 2080/LX3

The Meade 2080/LX3 with built-in quartz electronic drive system is positively the highest performance 8" Schmidt-Cassegrain telescope system available today.

FEATURES OF THE MEADE 2080/LX3

- ★ Certified diffraction-limited system
- ★ Built-in quartz microelectronic sidereal drive system
- ★ 8x50mm right-angle illuminated Polar viewfinder
- ★ Multi-coated prism star diagonal (99% transmission)
- ★ 25 ft. cord for field operation from a 12V car battery
- ★ 25 ft. cord w/converter for 110VAC 50/60Hz operation
- ★ Output jacks for illum. reticle eyepiece and map light
- ★ Equatorial wedge with compass, bubble level, micrometric azimuth control
- ★ Piggyback camera mount for effortless wide-field photography **(Best to photograph Comet Halley!)**
- ★ Audio cassette explains features, set-up, visual & photographic applications
- ★ Lifetime warranty on telescope, wedge, tripod
- ★ 8" f/10 Schmidt-Cassegrain optics, F = 2000mm
- ★ 20mm Research-Grade Erfle 1¼" eyepiece (100X)
- ★ 7mm Research-Grade Orthoscopic eyepiece (286X)
- ★ High transmission coatings on the front corrector lens
- ★ Ultraprecision 6" LX worm gear motor drive
- ★ Oversize 8.25" primary mirror benefits photography
- ★ Convenient fork mount with slow motion controls
- ★ Best overall mechanical stability of any 8" Cassegrain
- ★ Large right ascension & declination setting circles
- ★ Padded carrying case
- ★ Eyepiece rack
- ★ Latitude scale and no-tool knob set
- ★ Adjustable height heavy duty tripod with eyepiece rack
- ★ Dew shield & accessory tray, optional **add $88**
- ★ Star map & finder cards for Messier objects
- ★ Red astronomer's night flashlight
- ★ **Optional:** Multi-coated/silvered optics boost transmission 18%, **add $149**

2120/LX3 10" System w/MCSO $2690

The 10" Meade 2120/LX3 collects 56% more light than an 8" telescope for significantly improved viewing and astrophotography. It has all the features of the 2080/LX3 (see above.)

Meade 2120/LX3 w/wedge & tripod and with Multi-coated silvered optics (boosts transmission 18%)	**$2690**
Accessory shelf for field tripod ($40 list)	**$32**
#710 dew shield (10") Essential! ($140 list)	**$98**
#36 dual-axis drive corrector control box ($150 list)	**$99**
#38 declination motor and clutch ($150 list)	**$99**
LUMICON Giant EASY-GUIDER/Rich-Field viewer for f/4-f/10 operation (state camera)	**$395**

NEW! 2080/GEM and 2120/GEM

Schmidt-Cassegrain Optics on German Equatorial Mount

2080/GEM, 8" f/10 w/equatorial mount ($2100 list)	**$1150**
Multi-coated silvered optics, boost transmission 18%	**add $149**
2120/GEM, 10" f/10 w/equatorial mount **and with multi-coated silvered optics** ($4300 list)	**$2295**
Dew shield & accessory tray, 8" .... **$72** 10"	**$144**
#785 motor and quartz drive correc. system ($270 list)	**$198**
#3000 computer control system ($1500 list)	**add $895**

The Meade 2080/GEM and 2120/GEM telescopes include the same diffraction limited optics as the 2080/2120/LX3. Large, stable German equatorial mount with setting circles, slow motion controls on both axes, large 8X50mm finderscope, 25mm 1¼" eyepiece, integrated polar alignment scope, and heavy duty adjustable height tripod (hardwood for 2080, metal for 2120). The computer control provides automatic object location from an extensive software library of deep-sky objects.

4" MEADE 2045 w/table tripod $695

NEW! Meade 2045/LX3 w/quartz drive	**$885**

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Meade Model 2045 — Advanced engineering and superb optical performance in a beautiful ultraportable system.

FEATURES OF THE MEADE 2045

- ★ 4" f/10 Schmidt-Cassegrain optics, F=1000mm
- ★ Motor drive for automatic tracking, 110 VAC input
- ★ **LX3:** quartz-controlled elec. drive, 12VDC or 110VAC input
- ★ High transmission coatings on front corrector lens
- ★ Table tripod for easy polar alignment
- ★ 5X24 finderscope & 1¼" right-angle star diagonal
- ★ 1¼" 25mm (40X) and 9mm (111X) eyepieces
- ★ Fork mount with setting circles, manual slow motion

HIGHLY RECOMMENDED OPTIONS

Model 43 drive corrector uses 12VDC ($120 list)	**$96**
See Meade 2080/LX3 options	
Wedge & field tripod for Meade 2045 ($380 list)	**$298**
Dew shield ($70) .... **$49** Solar Filter ($180)	**$139**

OPTIONS BOOST PERFORMANCE

LUMICON UHC Filter for nebulae. Standard 1¼"	**$79**
Prem 1¼", **$99**; Std 48mm, **$159.50**; Prem 48mm,	**$199.50**
LUMICON Deep-Sky Filter, 1¼" Premium	**$79**
48mm Prem Deep-Sky ..... **$119.50, $99.95** w/Easy-Guider	
Adapter for viewing w/1¼" eyepiece	**$20**
Dust covers. Keep optics clean. For 6"	**$16/pair**
8" .... **$20/pair;** 10" .... **$18;** 16"	**$24**
LUMICON Rich-Field Viewer (2080)	**$140**
LUMICON Newtonian Easy-Guider, 1¼" or 2"	**$169**
#122 2X Barlow ($60 list)	**$48**
Dual-axis drive corr. and elec. dec. for 2080/LX2	**$298**
for model 628, 826, DS-10 .... **$340** for DS-16	**$440**
Tele Vue 32mm Plossl 1¼" eyepiece	**add $99**
LUMICON Cassegrain EASY-GUIDER for 2080/LX2 & LX/3 (state camera)	**$225**
Illuminated reticle eyepiece & battery pack	**$79.50**

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8" f/6 NEWTONIAN.........$995

SALE

$698
(Model 628)

$798
(Model 628C)
6" f/8 with
motor drive

Model 826, 8" f/6 Telescope w/accessories

Model 628, 6" f/8 with motor drive ($1220 list)	**$698**
Model 628C, 628 w/2" focuser, 8x50mm finder ($1450	**$798**
Model 826C, 8" f/6 with motor drive, #680 2" focuser and 8x50mm finderscope ($1590 list)	**$995**

—Collects 78% more light than a 6" telescope.

These Meade Deluxe Series reflecting Telescopes have superb image quality at low or high power. They include an equatorial mount with motor drive, pier, legs, setting circles, 2" rack & pinion focuser, 8X50 finderscope (628C & 826C only), 25mm (48X) and 9mm (135X) 1¼" eyepieces, altitude and azimuth fine adjustments for polar alignment.

#43 drive corrector uses 12VDC ($120 list)	**$96**
#47M Dual-axis drive corrector & elec. dec.	**$340**
1¼" or 2" EASY-GUIDER (state camera)	**$169**

6" f/5 NEWTONIAN........$695

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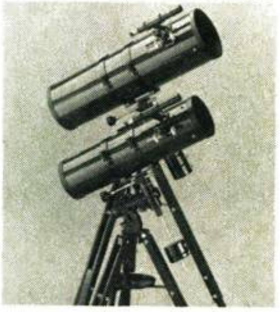

Models 6600 (6" f/5) & **8800** (8" f/4.5) telescopes

Model 6600, 6" f/5 Newtonian telescopes ($1300 list)	**$695**
—Best performance & value; bright, wide views.	
Model 8800, 8" f/4.5 Newtonian Telescopes ($1700)	**$895**
—Collects 78% more light than a 6" telescope.	

These Meade Professional Series reflecting telescopes yield superb rich-field viewing w/bright images. They include an equatorial mount w/adjustable tripod, setting circles, slow motion controls, 6x30mm view-finder, 1¼" focuser, 25mm & 9mm 1¼" eyepieces & accessory tray.

#784 Quartz motor & quartz drive corrector ($270 list)	**$198**
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1¼" LUMICON Easy-Guider (state camera)	**$169**

16" f/4.5 NEWTONIAN......$1995

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The DS Series of 10" and 16" reflecting telescopes are ideal for deep-sky viewing and photography.

DS-10A, 10" f/4.5 with motor drive ($1600 list)	**$995**
—Gathers 56% more light than an 8" telescope	
DS-16A, 16" f/4.5 with motor drive ($3140 list)	**$1995**
Sealmaster ball bearings, highly recommended	**add $229**
—Gathers 400% more light than an 8" telescope	

Both the DS-10A and DS-16A telescopes include an equatorial mount, #680 2" focuser, motor drive, setting circles and 25mm 1¼" eyepieces. The DS-10A is shipped freight collect.

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8x50mm finderscope with brackets ($130 list)	**$96**

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ANNOUNCEMENT — The Computer Astronomy Network is a non-profit group of computer users/amateur astronomers who exchange programs and share techniques. Send correspondence to Barry Malpas, 20 Helen Street, Warren, NJ 07060. Dues to cover newsletter costs are $3 annually.

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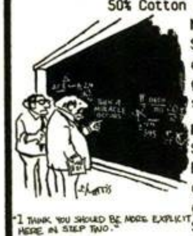
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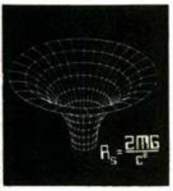

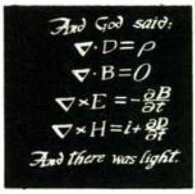
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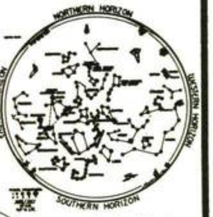

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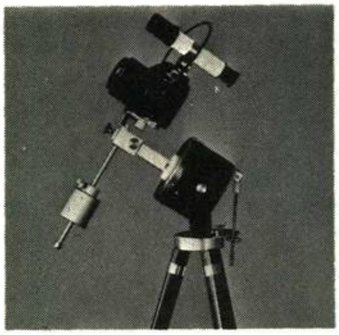

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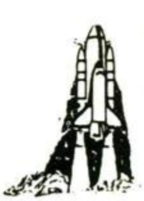

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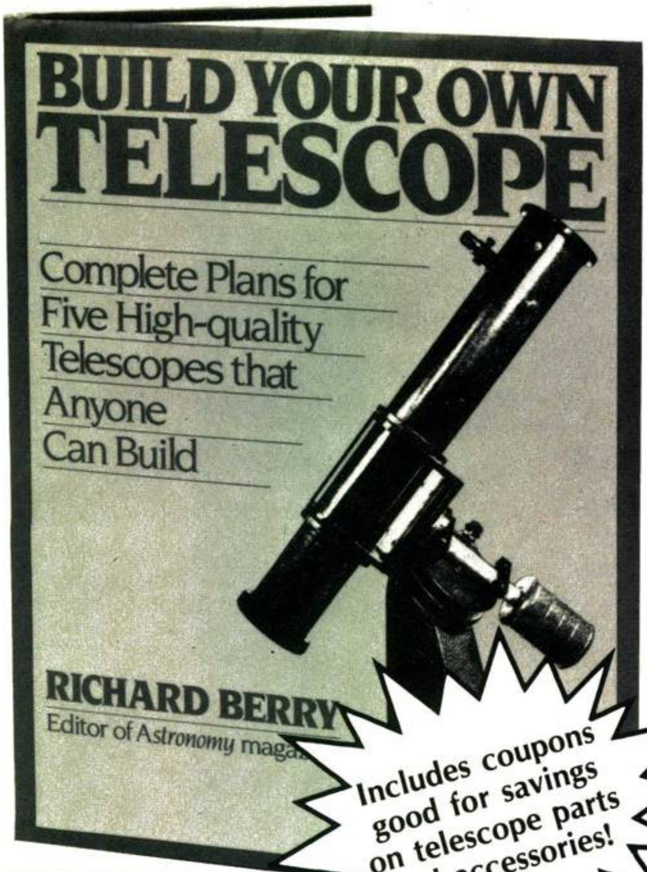
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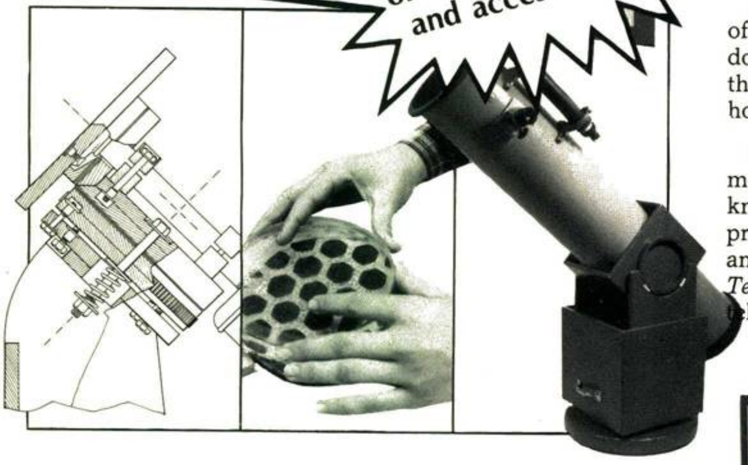

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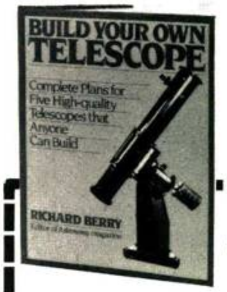

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The View From eur

by Sheridan Simon

Space probes from Earth have now closely approached or landed on all of the planets and major moons from Mercury out to distant Uranus. The photographs they beamed back to us have turned blurred specks in the night sky into worlds as real as the one we live on, making our generation the first to see landscapes that were formed nearly 5 billion years ago. One such landscape is that of Europa, the sixth moon of Jupiter.

Imagine yourself as part of an expedition to the moons of Jupiter a generation or more in the future, when sophisticated spacecraft can carry people and equipment across the more than 600 million kilometers that separate Earth from Jupiter and its sixteen known satellites.

You have just landed on Europa, the fourth largest of these moons, and are about to conduct the first reconnaissance of the landing site. The pilot of your craft has brought you down on the moon's equator, right in the center of the Jupiter-facing hemisphere. Like our own moon, Europa is tidally locked, with one side perpetually facing Jupiter and the other facing away from it.

After a thorough checkout of your spacesuit you descend to the frozen surface, reassured by the presence of the landing craft beside you. Looking around the landing area, the first thing you notice is how bright it is. You expected that the surface of Europa would be in a permanent gloom, barely lit by a sun that appears less than one-fifth the size it does on Earth. Yet even though the Sun is now setting it is still too bright to look at, since Europa has no atmosphere to dim the Sun's light.

The landscape is the translucent white color of an ice-covered lake, and like ice the surface crunches lightly underfoot as you walk. You have to exercise caution with each step, however, because the surface is slippery and the gravity is very weak. Just two-thirds the mass of our moon and only a fraction smaller, Europa's surface gravity is about 80 percent that of the Moon and less than one-seventh of what you are used to on Earth.

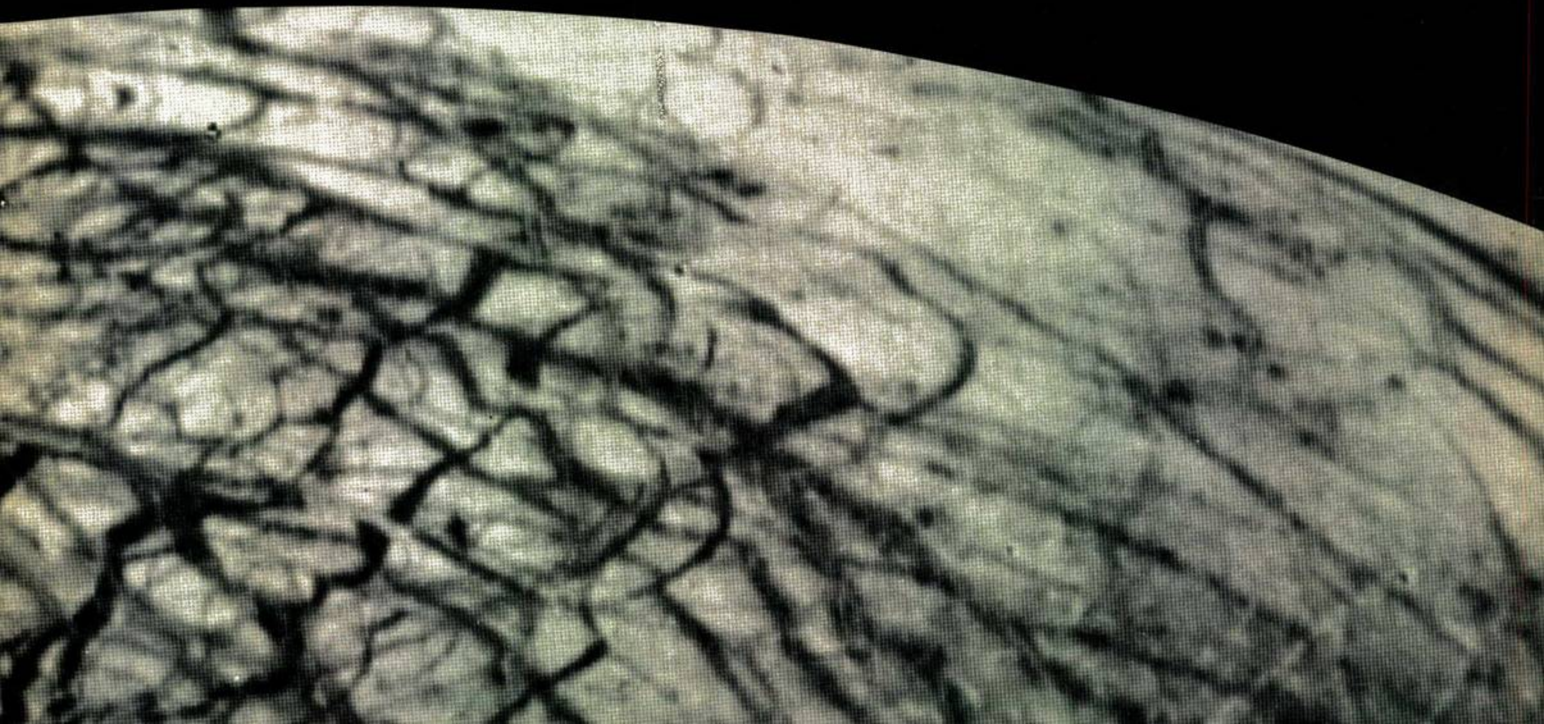
Bending carefully you touch the surface. It feels like ice through your glove, hard and slippery. Suddenly, you jerk your hand back. That icy surface is *cold*, 130 degrees below zero Celsius (−200°F) or more. You won't touch it again if you can avoid it, except with your heavily insulated boots.

Lifting your gaze from the ground toward the horizon you notice two things in quick succession: the horizon seems too close, and there seems to be nothing much to look at. With a radius only one-quarter that of Earth, Europa's horizon is barely two and a half kilometers distant, only half as far away as what you are used to.

Furthermore, the landscape seems downright boring. Europa is very flat with only a hundred meters or so separating its highest and lowest points. Its icy crust is much more fragile and brittle than rock, so if tall mountains or deep canyons ever formed on Europa they would not have lasted for any length of time. Ice mountains would collapse under their own weight and canyons would fill in as the glacial walls that bounded them squeezed slowly together. The biggest difference between various places on Europa's surface is color — dull grays and browns that stain the general whiteness of the ice.

Disappointed, you lift your eyes to the sky and almost fall over backward. The biggest planet in the solar system looks as if it is going to fall on you at any moment.

The sight of Jupiter hanging in the sky makes you feel disoriented. It seems as if the huge planet is actually "down" and you are hanging from a flat icy surface above it, with no handholds within reach. You always knew Jupiter was big, some eleven times the diameter of Earth and over three hundred times



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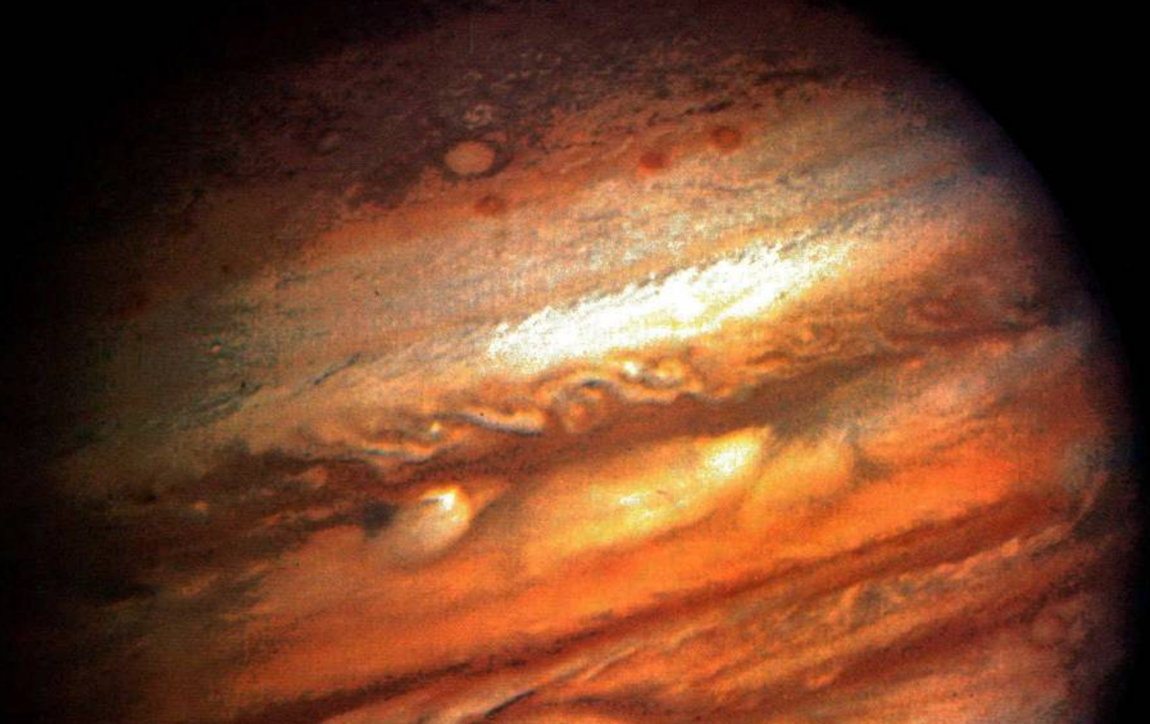
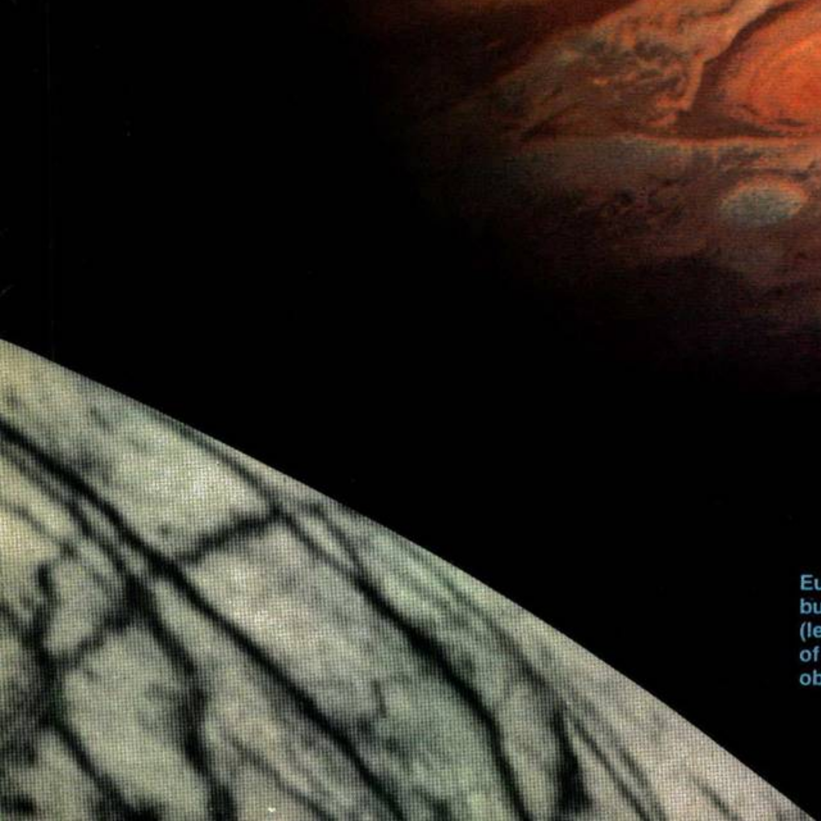




Europa may be the smallest of the four major moons of Jupiter, but it is certainly not the dullest. The strangely patterned surface (left) forms an interesting contrast to the banded atmosphere of Jupiter (above), which is just one of the impressive vistas observable from Europa. NASA/JPL images.

Io
Jupiter
Moon

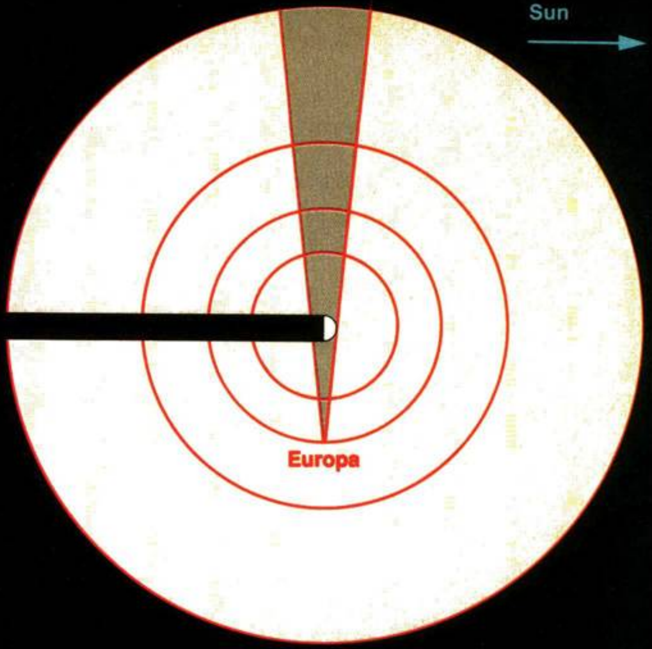
Earth's mass, but until seeing it directly over your head you hadn't been able to visualize exactly what that meant.

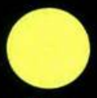
Holding your gloved hand straight up at arm's length with fingers spread doesn't even cover the whole face of the planet. Europa is less than 700,000 kilometers from the surface of Jupiter, only 75 percent more than the distance from Earth to the Moon. However, Jupiter covers 12° of the sky, which is more than twenty times the diameter of the Moon as seen from Earth.

Like our Moon, Jupiter exhibits phases as Europa orbits the planet. The phases complete one cycle every three and a half days, which is the time it takes Europa to circle Jupiter. With the Sun near your horizon, Jupiter is at half phase, a fine situation in which to enjoy your first close-up, naked-eye look at the planet. The night side gradually brightens into day as the thick atmosphere produces a long sunrise.

The swirling reds and whites of the cloud layers on the lighted half drift majestically across the giant face of the planet. The boiling, churning motions create an illusion of slowness from this distance, but you know that winds of hundreds of kilometers an hour hurl those colored clouds across Jupiter's sky.

The biggest feature of them all, the Great Red Spot, covers an area larger than a dozen Full Moons. Observed by earthbound astronomers since the seventeenth century, it looks like a gigantic hurricane. It is easily big enough to swallow the entire Earth.





An everchanging display of Jovian moons awaits the visitor to Europa. In the diagram above, our intrepid explorer sees each satellite disappear twice during each trip around the Europan sky. From a spot on the Jupiter-facing hemisphere (marked by the vertex of the angle), each moon is invisible both when it passes behind Jupiter and again when it passes through the planet's shadow. Io watchers would also observe that world transit across the face of Jupiter.

Relative sizes of the various objects visible from Europa are shown at left compared to the apparent size of the Moon as seen from Earth. Each of the Jovian moons is shown as it would appear at full phase on its closest approach to Europa. Seeing all of them would require observations from both hemispheres. Note both the huge size of Jupiter and the smallness of the Sun, only one-fifth as large as Earth observers see it. Photo of the Full Moon by Larry Rinker; Jupiter and satellite photos from NASA/JPL.

As the minutes pass you can see the tremendous storm rotate a little, the speed of its winds diminished by the sheer magnitude of the Spot itself. The Spot seems to have shifted slightly as well, carried along by the rapid rotation of the massive planet. Jupiter rotates on its axis in less than 10 hours, so its effects are easy to see from your superb vantage point.

Not far from Jupiter you catch a glimpse of something that momentarily reminds you of the Moon. You grin to yourself upon realizing that the only similarity is size, but even so Io looks a bit bigger than the Moon does when seen from Earth. Io is actually only a trifle larger than the Moon, but at the moment you are somewhat closer to Io than the Moon is to Earth. At its closest, when the copper-colored moon is in transit across the face of Jupiter, it looks half again the size of the Full Moon as seen from Earth. When Io passes behind the limb of Jupiter it is more than four times as far away and looks correspondingly smaller, only about one-third the size of the Full Moon.

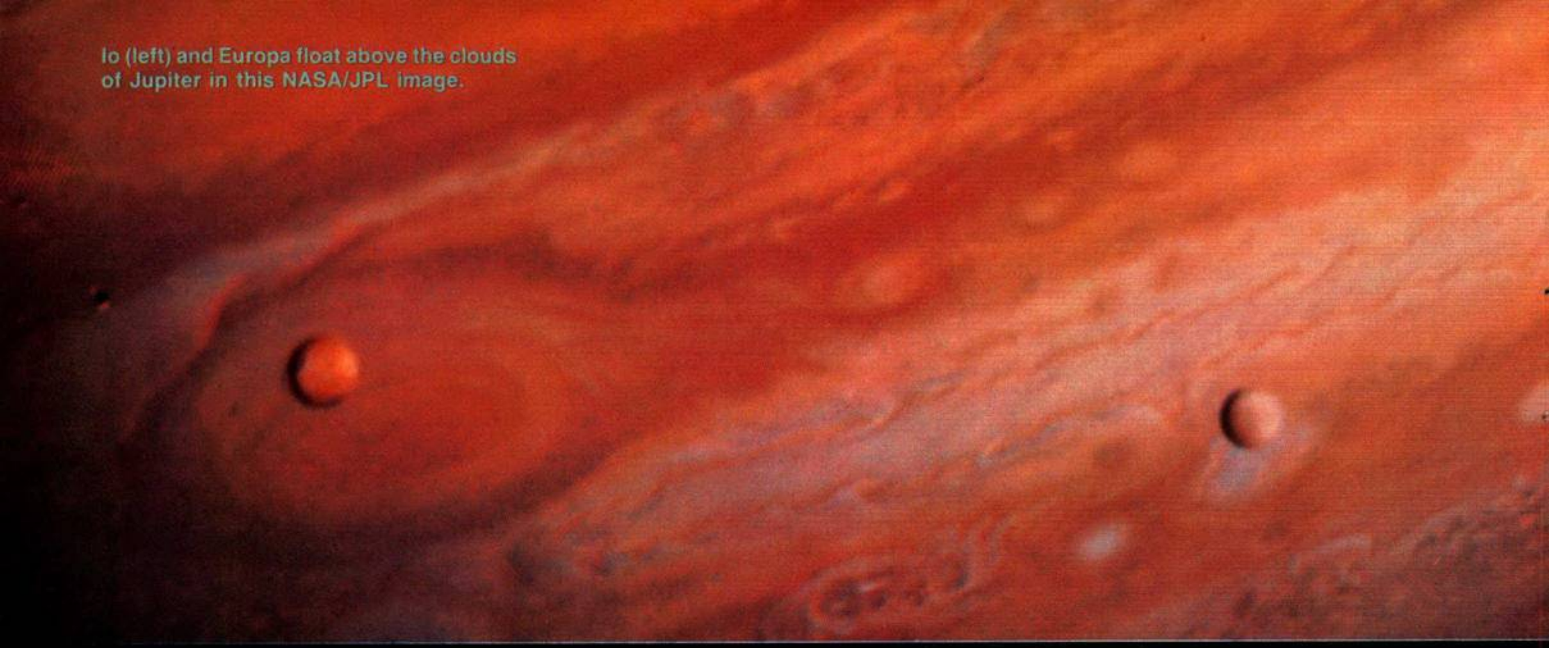
At the moment Io is in a crescent phase close to the Sun in the sky and details are difficult to see. Squinting you wish the Sun would set so that its glare off the icy plain would not distract you. A "day" on Europa lasts three and a half Earth days, so the Sun moves across the sky more slowly than you are used to.

As if on cue the Sun touches the strangely close horizon, for an instant becoming a dazzling sphere resting on the frigid plain. Slowly, steadily, as if it was melting its way into the frozen crust, the Sun gradually sinks. Within two minutes the last sliver of it has vanished and night has come to Europa.

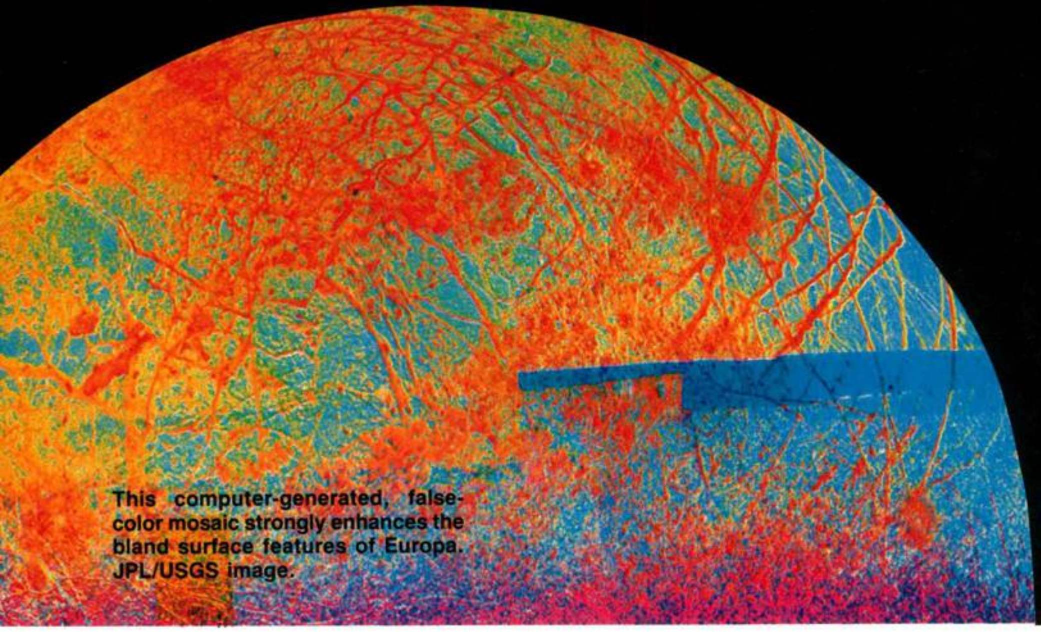
Even after sunset it is far from dark. In half phase Jupiter reflects more than one hundred times as much sunlight as the Full Moon does on a cloudless night on Earth. It is easy to see the flat Europan plains, somber orange in the light of Jupiter. It is bright enough to read by, though your eyes might tire from the colored illumination.

You can see more of the crescent Io now that the Sun has set. White smears seem to cover part of the lighted surface, and the dominant red hue displays darker and lighter shades. Io is *much* more colorful than the Moon. In the dark portion of the globe between the horns of the crescent you can see some tiny reddish glows. Whether daylit or dark, Io's dozen active volcanoes continue their eruptions, supplied with energy by the ceaseless tidal stretching and squeezing applied by Jupiter. The hot gases and lava pouring through Io's thin crust glare across the nearly 400,000 kilometers separating the two great moons.

Near the horizon opposite the point where the Sun just set you see another Moon-sized object, this one nearly full. You recognize it from the old Galileo spacecraft images as Ganymede, another of the four satellites discovered by Galileo. No



Io (left) and Europa float above the clouds of Jupiter in this NASA/JPL image.



This computer-generated, false-color mosaic strongly enhances the bland surface features of Europa. JPL/USGS image.

Above: This view of Europa is close to what you might see as you approached it in a spacecraft — a mostly white sphere crisscrossed by a faint network of slightly darker lines. NASA/JPL photo.

one would mistake this one for the Moon; it reminds you more of Earth as seen from lunar orbit. The dominant color is brown, with a deep blue in both polar regions. White swirls and spots adorn the globe as well. Vaguely reminiscent of clouds, you know that no matter how long you look these "clouds" will never move. They are not clouds at all but glimpses of the icy mixture that comprises the bulk of Ganymede.

Like Europa, Ganymede is colder than any Antarctic winter night. Most of the white regions are layers of ice that were originally below the surface and have been exposed by relatively recent meteor strikes that vaporized the dirtier topmost layers.

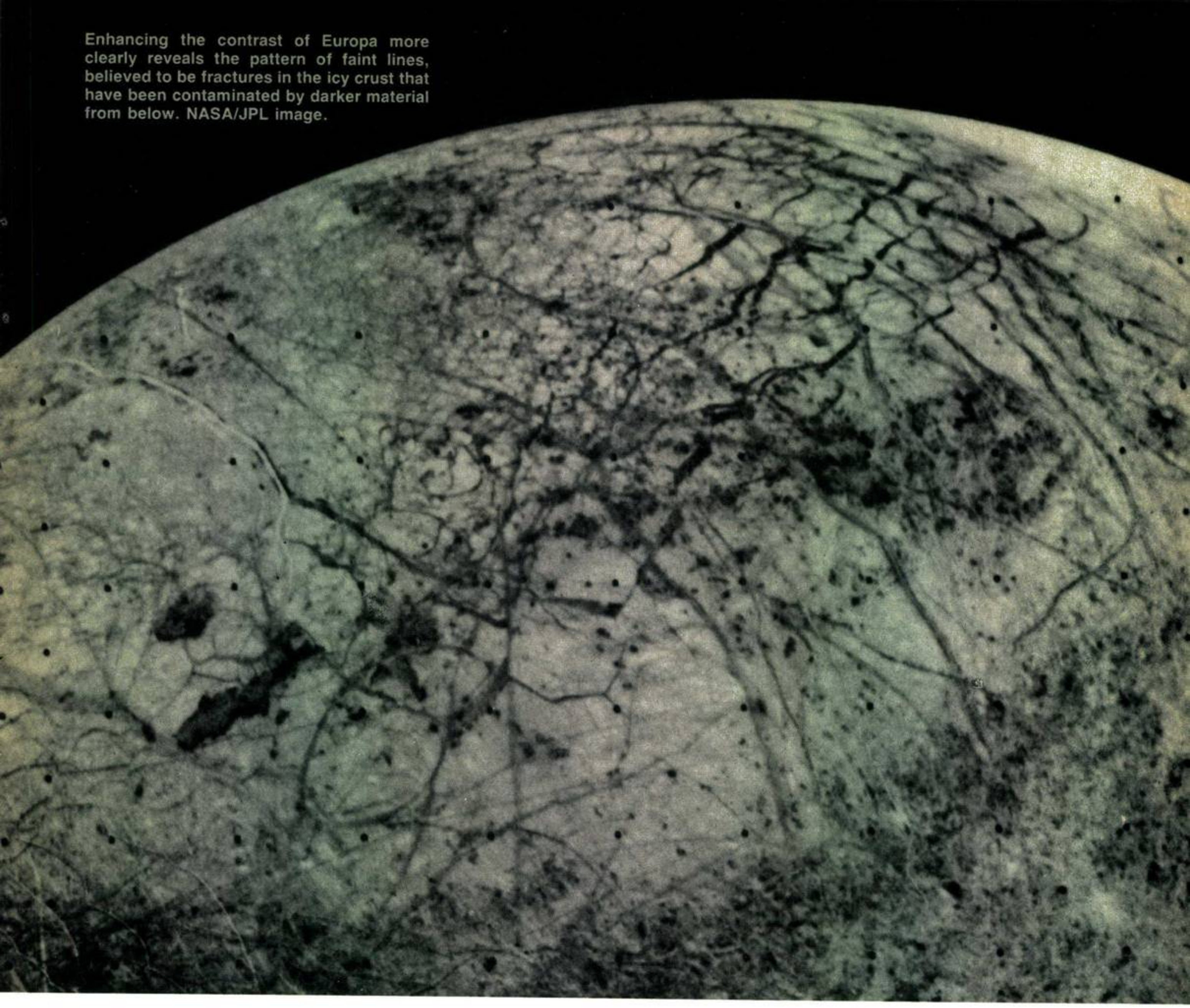
Ganymede does not seem as bright as the Moon does from Earth. Despite a larger and more reflective surface, Ganymede is more than five times as far from the Sun as is our moon and so receives less than 4 percent as much sunlight per square meter.

For a time you look in vain for the fourth Galilean satellite, Callisto. You have just about decided that it must be below the horizon when you notice it emerging from beyond the dark limb of Jupiter. Callisto looks tiny at this distance, 2.5 million kilometers away. It is only one-quarter the size of the Moon as seen from Earth and is a duller color than either Io or Ganymede. Its polar regions look light gray and its equatorial belly is circled by a patchy yellowish belt. At times you know it looks nearly twice as large, but not from this spot on the Jupiter-facing hemisphere of Europa. When Callisto is closest to Europa it is visible only from the opposite hemisphere, where Jupiter never rises.

There is an intricate, ever-changing pattern of moons to look at in the sky. Io goes through its complete cycle of phases in three and a half days, swinging from its present position farther and farther from Europa until it passes behind the massive planet, where it remains invisible for over seven hours.

After re-emerging, Io steadily closes the distance between the two moons, finally drifting across Jupiter's giant face in a ridiculous attempt to eclipse it. It takes Io less than two hours to pass in front of Jupiter as it either chases or is followed by its smaller dark shadow on the colored cloud layers far below. Twelve hours later the reddish moon is nearly 40° from Jupiter, as far as it ever gets as seen from Europa, after which it swings back to its original position. The only other time Io leaves Europa's sky is when it passes through Jupiter's shadow, a trip that takes two and a quarter hours.

Ganymede, farther from Jupiter than Europa, follows a path that takes it below your horizon. It swings in a great circle through the sky, taking it a bit over seven days to complete the trip. It never crosses the face of Jupiter, but it is invisible for two brief periods while above the horizon. During one of these periods Ganymede passes through Jupiter's shadow. Ganymede is about two and a half times as far from Jupiter as Io is, so the shadow



Enhancing the contrast of Europa more clearly reveals the pattern of faint lines, believed to be fractures in the icy crust that have been contaminated by darker material from below. NASA/JPL image.

blocks a slightly smaller portion of its orbit. This is more than compensated for by Ganymede's slower orbital motion, which lengthens the passage. The net result is that the eclipse lasts about three and a half hours.

During the second period of invisibility Ganymede passes behind the planet itself. Because Jupiter looms large in Europa's sky, it blocks the view of Ganymede for over nine hours. Still, the moon is visible most of the time it is above the horizon, and, of course, there are never any clouds to hide it. Even after Ganymede sets it is not below the horizon very long, about two days out of seven.

Like Ganymede, Callisto is both eclipsed by Jupiter's shadow and occulted by the planet itself. The shadow eclipse takes nearly five hours, longer than Ganymede's because of Callisto's slower orbital motion around Jupiter. But because Callisto moves so slowly, Europa's motion determines how fast the moon appears to move. Callisto stays hidden behind Jupiter for only around five hours out of the four and a half days it takes to travel across Europa's sky.

Jupiter has plenty of satellites in addition to the famous Galilean quartet. The eight tiny outer moons are never visible to the naked eye from Europa, but you have a good chance of spotting the inner ones — Adrastea, Metis, Amalthea, and Thebe. They are much too small to resemble anything but stars, but the biggest, Amalthea, is about as bright as the stars in Orion's Belt. It never gets very far from Jupiter in the sky, no more than about 16°, but it might be spotted by its rapid motion.

As seen from Europa, Amalthea circles Jupiter in less than fourteen hours, fast enough to be seen creeping against the background stars. You try hard, but you can't be sure you've spotted any of the inner moons. There are too many stars competing with them in the black sky, and Jupiter's overwhelming presence makes them hard to see in any case.

A tone sounds in your helmet and you glance quickly at a digital read-out. You have only ten minutes worth of oxygen remaining. It's time to go back into the warmth and air inside the lander. Regretfully you turn to mount the short ladder to the air lock, being careful as you move in the low gravity on the slippery surface.

One last object catches your eye as you begin to enter the lock. From this vantage point Saturn appears as only a fairly bright star, yet you send it a brief smile of recognition as the lock door closes.

Sheridan Simon is an associate professor of physics at Guilford College in Greensboro, North Carolina. In addition to research interests in stellar structure and evolution, he designs hypothetical planets for science fiction writers.

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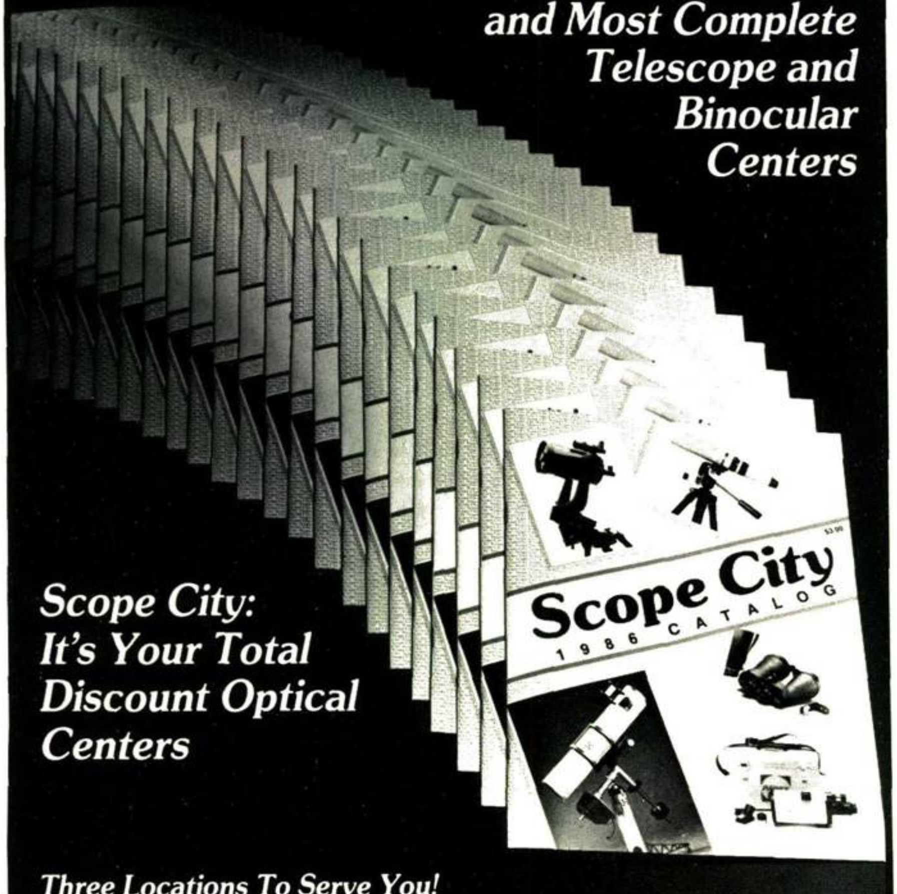
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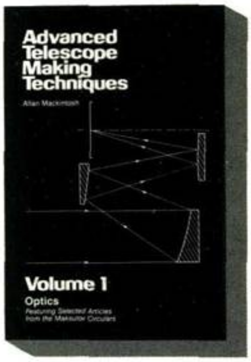
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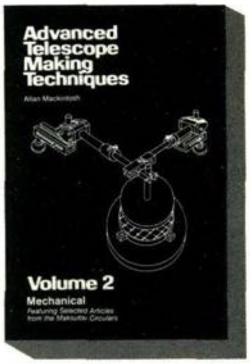
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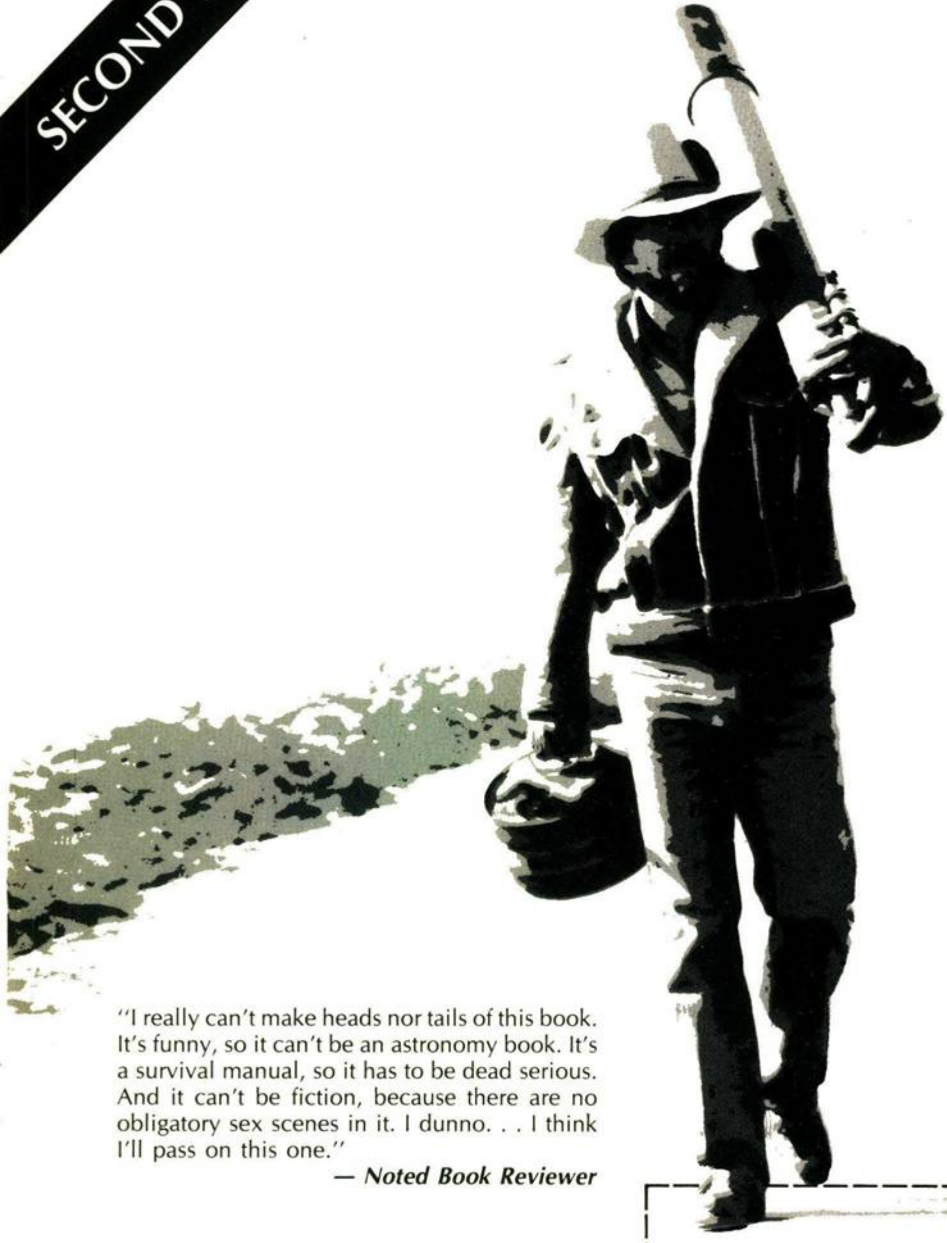

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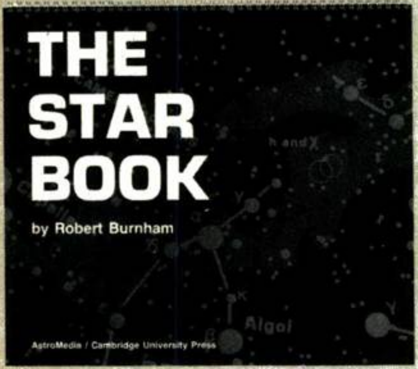

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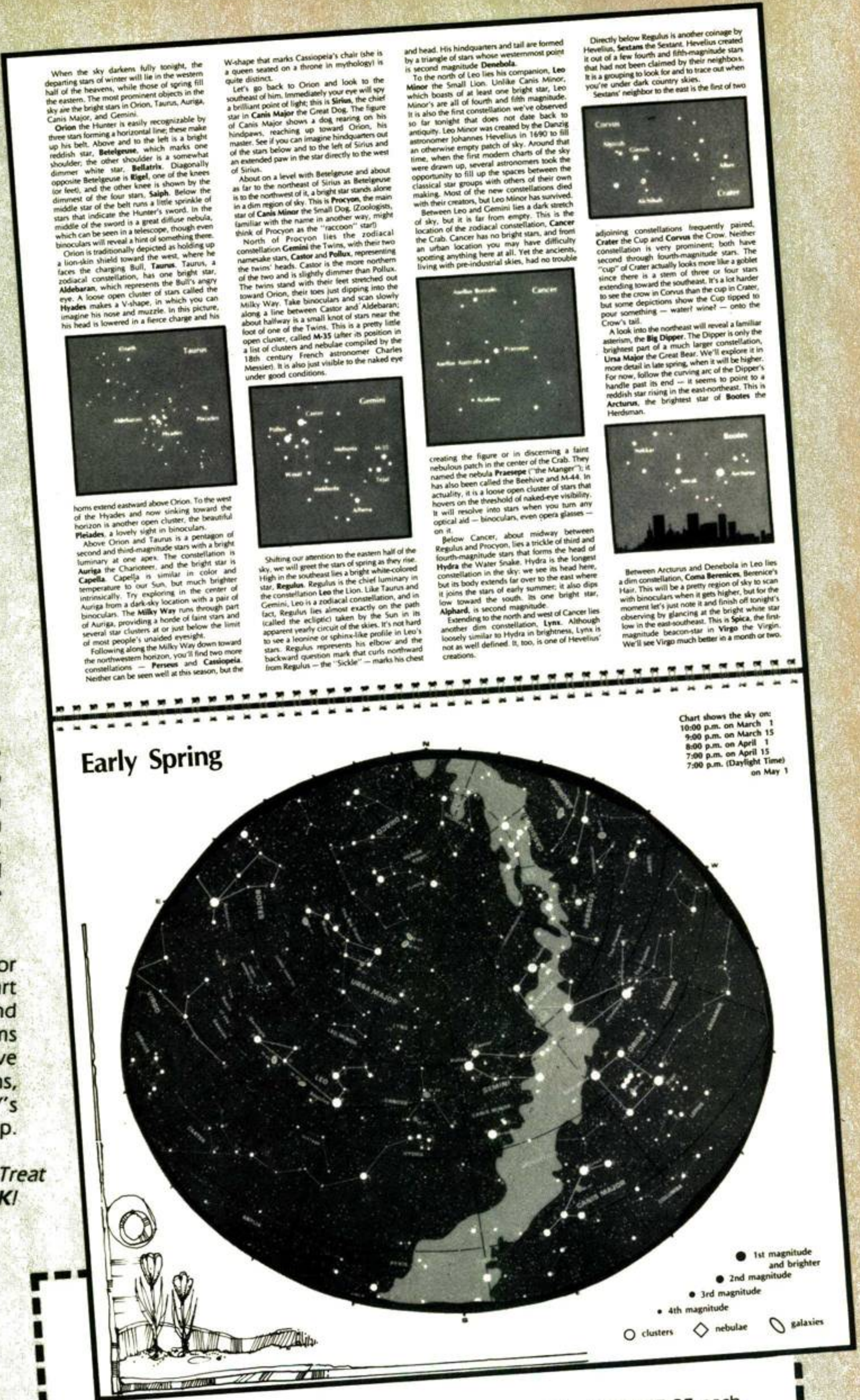

When the sky darkens fully tonight, the departing stars of winter will lie in the western half of the heavens, while those of spring fill the eastern. The most prominent objects in the sky are the bright stars in Orion, Taurus, Auriga, Canis Major, and Gemini.

Orion the Hunter is easily recognizable by three stars forming a horizontal line; these make up his belt. Above and to the left is a bright reddish star, **Betelgeuse**, which marks one shoulder; the other shoulder is a somewhat dimmer white star, **Bellatrix**. Diagonally opposite Betelgeuse is **Rigel**, one of the knees (or feet), and the other knee is shown by the dimmest of the four stars, **Saiph**. Below the middle star of the belt runs a little sprinkle of stars that indicate the Hunter's sword. In the middle of the sword is a great diffuse nebula, which can be seen in a telescope, though even binoculars will reveal a hint of something there.

Orion is traditionally depicted as holding up a lion-skin shield toward the west, where he faces the charging Bull, **Taurus**. Taurus, a zodiacal constellation, has one bright star, **Aldebaran**, which represents the Bull's angry eye. A loose open cluster of stars called the **Hyades** makes a V-shape, in which you can imagine his nose and muzzle. In this picture, his head is lowered in a fierce charge and his

horns extend eastward above Orion. To the west of the Hyades and now sinking toward the horizon is another open cluster, the beautiful **Pleiades**, a lovely sight in binoculars.

Above Orion and Taurus is a pentagon of second and third-magnitude stars with a bright luminary at one apex. The constellation is **Auriga** the Charioteer, and the bright star is **Capella**. Capella is similar in color and temperature to our Sun, but much brighter intrinsically. Try exploring in the center of Auriga from a dark-sky location with a pair of binoculars. The **Milky Way** runs through part of Auriga, providing a horde of faint stars and several star clusters at or just below the limit of most people's unaided eyesight.

Following along the Milky Way down toward the northwestern horizon, you'll find two more constellations — **Perseus** and **Cassiopeia**. Neither can be seen well at this season, but the W-shape that marks Cassiopeia's chair (she is a queen seated on a throne in mythology) is quite distinct.

Let's go back to Orion and look to the southeast of him. Immediately your eye will spy a brilliant point of light; this is **Sirius**, the chief star in **Canis Major** the Great Dog. The figure of Canis Major shows a dog rearing on his hindpaws, reaching up toward Orion, his master. See if you can imagine hindquarters out of the stars below and to the left of Sirius and an extended paw in the star directly to the west of Sirius.

About on a level with Betelgeuse and about as far to the northeast of Sirius as Betelgeuse is to the northwest of it, a bright star stands alone in a dim region of sky. This is **Procyon**, the main star of **Canis Minor** the Small Dog. (Zoologists, familiar with the name in another way, might think of Procyon as the "raccoon" star!)

North of Procyon lies the zodiacal constellation **Gemini** the Twins, with their two namesake stars, **Castor** and **Pollux**, representing the twins' heads. Castor is the more northern of the two and is slightly dimmer than Pollux. The twins stand with their feet stretched out toward Orion, their toes just dipping into the Milky Way. Take binoculars and scan slowly along a line between Castor and Aldebaran; about halfway is a small knot of stars near the foot of one of the Twins. This is a pretty little open cluster, called **M-35** (after its position in a list of clusters and nebulae compiled by the 18th century French astronomer Charles Messier). It is also just visible to the naked eye under good conditions.

Shifting our attention to the eastern half of the sky, we will greet the stars of spring as they rise. High in the southeast lies a bright white-colored star, **Regulus**. Regulus is the chief luminary in the constellation **Leo** the Lion. Like Taurus and Gemini, Leo is a zodiacal constellation, and in fact, Regulus lies almost exactly on the path (called the ecliptic) taken by the Sun in its apparent yearly circuit of the skies. It's not hard to see a leonine or sphinx-like profile in Leo's stars. Regulus represents his elbow and the backward question mark that curls northward from Regulus — the "Sickle" — marks his chest and head. His hindquarters and tail are formed by a triangle of stars whose westernmost point is second magnitude **Denebola**.

To the north of Leo lies his companion, **Leo Minor** the Small Lion. Unlike Canis Minor, which boasts of at least one bright star, Leo Minor's are all of fourth and fifth magnitude. It is also the first constellation we've observed so far tonight that does not date back to antiquity. Leo Minor was created by the Danzig astronomer Johannes Hevelius in 1690 to fill an otherwise empty patch of sky. Around that time, when the first modern charts of the sky were drawn up, several astronomers took the opportunity to fill up the spaces between the classical star groups with others of their own making. Most of the new constellations died with their creators, but Leo Minor has survived.

Between Leo and Gemini lies a dark stretch of sky, but it is far from empty. This is the location of the zodiacal constellation, **Cancer** the Crab. Cancer has no bright stars, and from an urban location you may have difficulty spotting anything here at all. Yet the ancients, living with pre-industrial skies, had no trouble

creating the figure or in discerning a faint nebulous patch in the center of the Crab. They named the nebula **Praesepe** ("the Manger"); it has also been called the Beehive and M-44. In actuality, it is a loose open cluster of stars that hovers on the threshold of naked-eye visibility. It will resolve into stars when you turn any optical aid — binoculars, even opera glasses — on it.

Below Cancer, about midway between Regulus and Procyon, lies a trickle of third and fourth-magnitude stars that forms the head of **Hydra** the Water Snake. Hydra is the longest constellation in the sky; we see its head here, but its body extends far over to the east where it joins the stars of early summer; it also dips low toward the south. Its one bright star, **Alphard**, is second magnitude.

Extending to the north and west of Cancer lies another dim constellation, **Lynx**. Although loosely similar to Hydra in brightness, Lynx is not as well defined. It, too, is one of Hevelius' creations.

Directly below Regulus is another coinage by Hevelius, **Sextans** the Sextant. Hevelius created it out of a few fourth and fifth-magnitude stars that had not been claimed by their neighbors. It is a grouping to look for and to trace out when you're under dark country skies.

Sextans' neighbor to the east is the first of two

adjoining constellations frequently paired, **Crater** the Cup and **Corvus** the Crow. Neither constellation is very prominent; both have second through fourth-magnitude stars. The "cup" of Crater actually looks more like a goblet since there is a stem of three or four stars extending toward the southeast. It's a lot harder to see the crow in Corvus than the cup in Crater, but some depictions show the Cup tipped to pour something — water? wine? — onto the Crow's tail.

A look into the northeast will reveal a familiar asterism, the **Big Dipper**. The Dipper is only the brightest part of a much larger constellation, **Ursa Major** the Great Bear. We'll explore it in more detail in late spring, when it will be higher. For now, follow the curving arc of the Dipper's handle past its end — it seems to point to a reddish star rising in the east-northeast. This is **Arcturus**, the brightest star of **Bootes** the Herdsman.

Between Arcturus and Denebola in Leo lies a dim constellation, **Coma Berenices**, Berenice's Hair. This will be a pretty region of sky to scan with binoculars when it gets higher, but for the moment let's just note it and finish off tonight's observing by glancing at the bright white star low in the east-southeast. This is **Spica**, the first-magnitude beacon-star in **Virgo** the Virgin. We'll see Virgo much better in a month or two.

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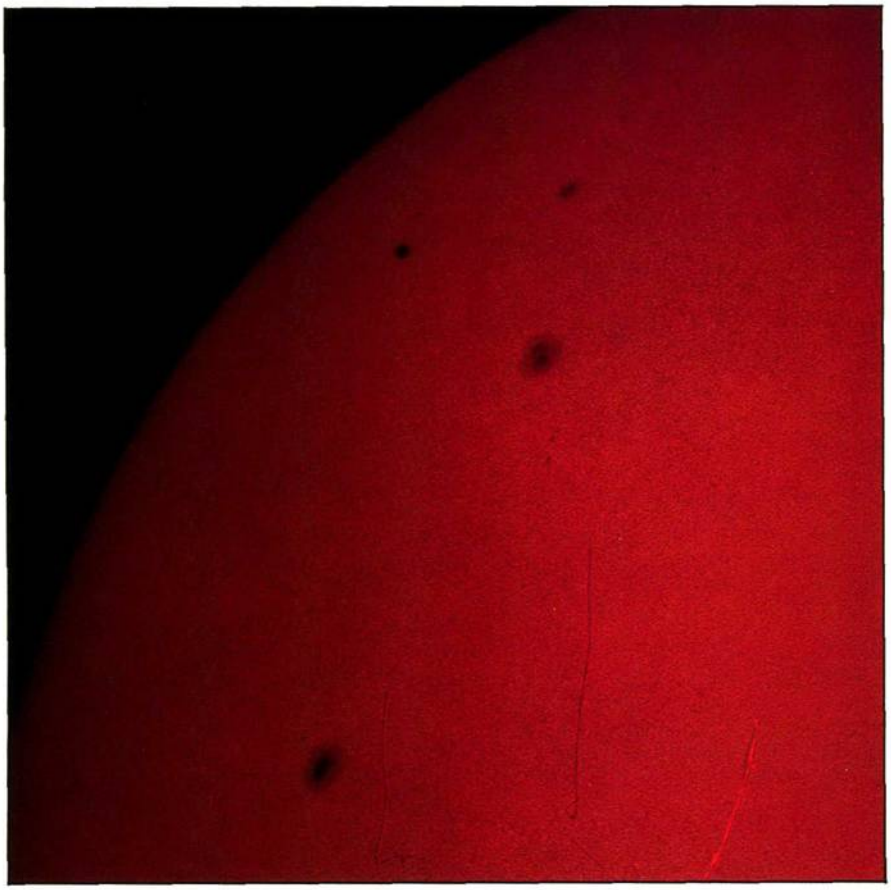
A Transit of Mercury



Bill Davis took this photo of the May 9, 1970, transit showing the round, dark dot of Mercury forming an equilateral triangle with two sunspots. The photograph was made with a 3.5-inch f/12 telescope and a full-aperture solar filter.

For those of us in North America, 1986 has not been the best year for observing rare astronomical events. First there was the once-in-a-lifetime appearance of Halley's Comet. Though Halley exceeded the expectations of many people and gave northerners a decent show, there is some lingering resentment that our friends in the Southern Hemisphere got the best display.

Now comes the November 13 transit of Mercury. As the disk of Mercury traverses the face of the Sun for the first time in thirteen years, night will have fallen in most of the Western Hemisphere; only observers living in southwestern Alaska will be able to see any of the transit. Most of the rest of the world, however, and especially the area including eastern Asia and Australia, will have an excellent view of the event.

A transit is the passage of a planet across the Sun's face. It occurs when either of the two inner planets, Mercury or Venus, comes directly between the Sun and Earth. Because of the great distance to these planets, however, their disks appear as little more than black dots crossing the solar disk.

Although the two inner planets pass between the Earth and Sun quite frequently (in a configuration known as inferior conjunction), transits do not occur at every such alignment. The orbits of Mercury and Venus are inclined to the orbital plane of Earth, or ecliptic, by 7° and 3.5°, respectively. This means that these planets spend most of their time either north or south of the ecliptic plane, and at most inferior conjunctions the planets pass north or south of the Sun.

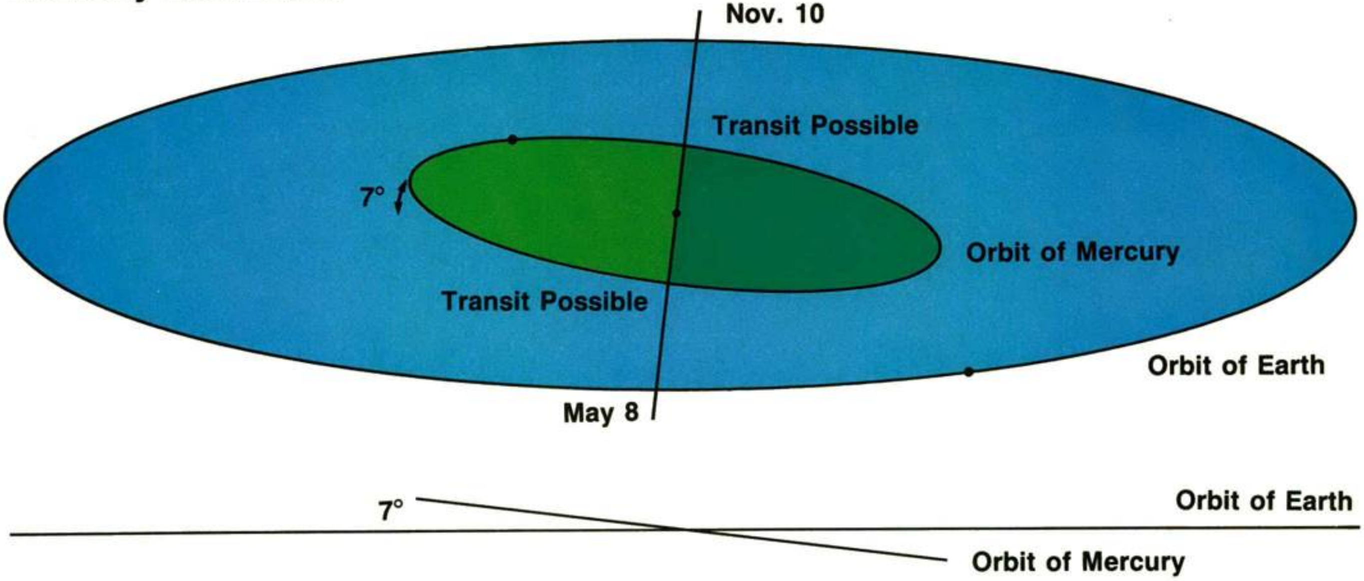
There are two times each orbit, however, when each planet passes through the ecliptic. Only on those rare occasions when inferior conjunction closely coincides to this passage can a transit take place. For Mercury these times are centered around May 8 and November 10.

On the average there are thirteen transits of Mercury each century. The last took place on November 10, 1973. Transits of Venus are even rarer because the number of possible transit dates around the planet's crossing of the ecliptic is smaller and the number of inferior conjunctions is fewer than in Mercury's case. Venusian transits occur in pairs; the transits in a pair are eight years apart and the pairs are separated by more than a century. The next Venusian transits will be on June 8, 2004, and June 6, 2012.

If you are lucky enough to see this transit, Mercury will appear as a slowly moving, small black dot silhouetted against the surface of the Sun. Use the sketch at the bottom of page 108 to follow the planet's path as it travels across the Sun's disk. Make sure to differentiate between the disk of Mercury, which looks completely black, and any sunspots, which are generally larger, have more complex shapes, and are not as dark.

The terms that describe the principal events of the transit are the same as those used in describing an annular solar eclipse. Contact I marks the instant when the disk of Mercury first makes contact with the solar limb. This occurs at approximately 1:43 Universal Time (UT) on November 13 at a position angle of 85°, which is just north of due east on the Sun's disk. Mercury will appear as a small

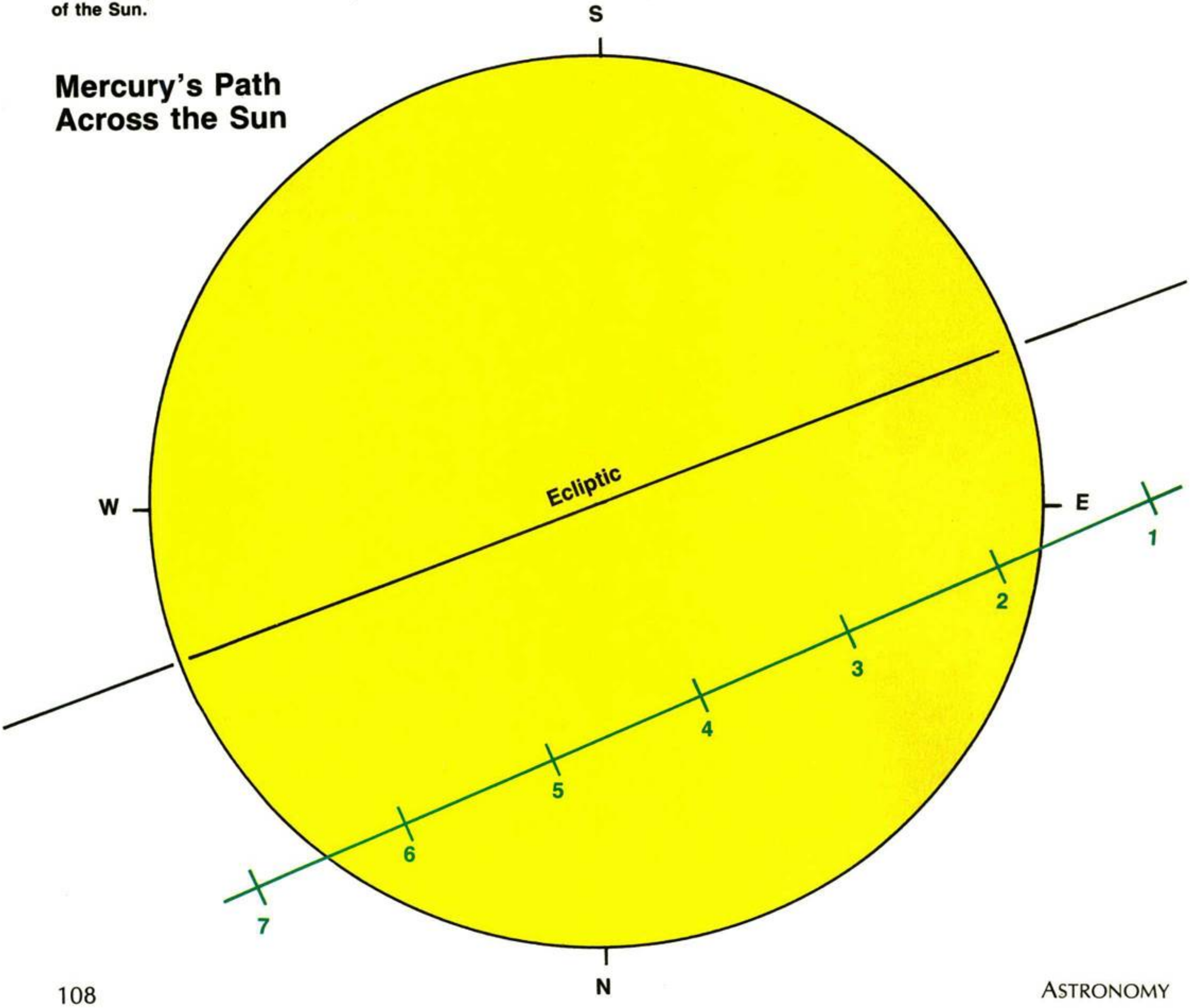
Orbits of Mercury and Earth


Nov. 10
Transit Possible
7°
Orbit of Mercury
Transit Possible
Orbit of Earth
May 8
7°
Orbit of Earth
Orbit of Mercury

Above: Transits of Mercury are only possible near May 8 and November 10, when Earth lies along the line of intersection between the orbital planes of the two planets. If Mercury reaches inferior conjunction at the same time, its disk will transit the face of the Sun.

Below: Mercury's predicted path across the solar disk takes it northwest from the eastern limb of the Sun. The planet's position is shown at each hour of Universal Time. Diagram courtesy Fred Espenak.

Mercury's Path Across the Sun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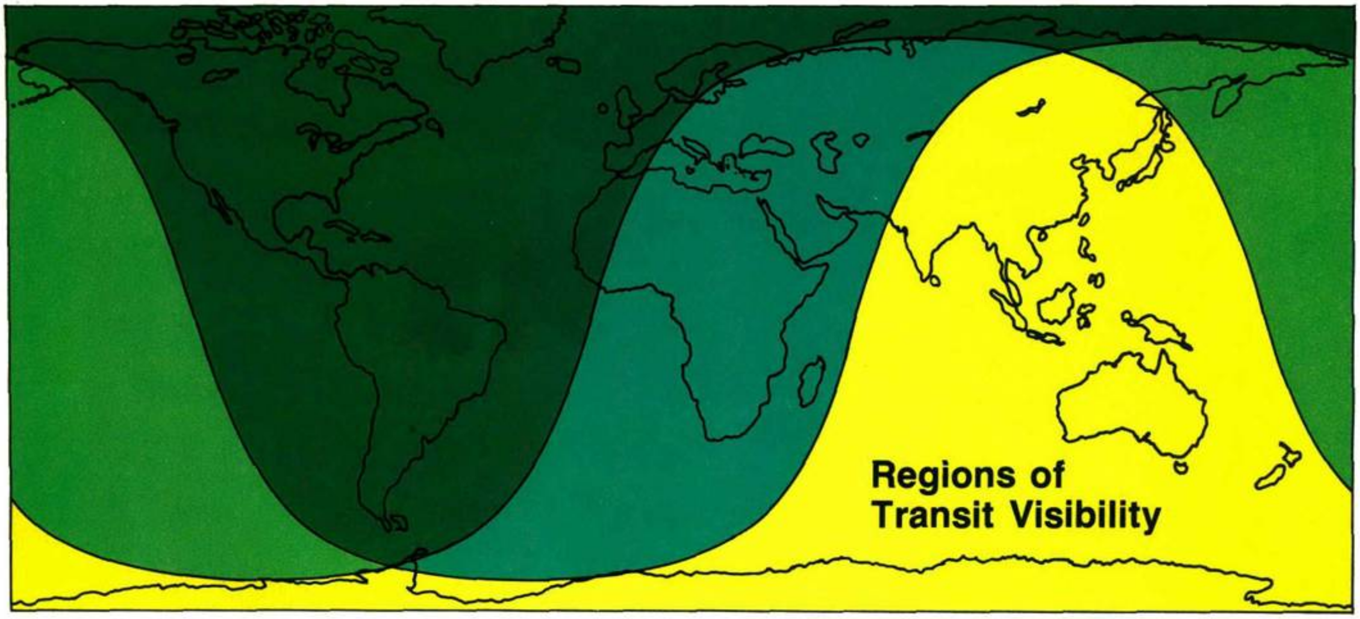


The best area from which to view the transit is the region of eastern Asia and Australia, though much of the world will see part of it. The Sun is at the zenith at maximum transit for viewers just off the northwest coast of Australia. Diagram courtesy Fred Espenak.

Transit Invisible

Start of Transit Visible

End of Transit Visible

Complete Transit Visible

indentation on the eastern edge of the Sun. Contact II comes about two minutes later as the trailing edge of Mercury's disk meets the solar limb. At this time the entire disk of Mercury is first visible.

For the next four and three-quarter hours the 9.9-arcsecond diameter disk travels northwest across the face of the Sun. Maximum transit, when the centers of the two bodies are closest to each other, is around 4:07 UT. At that time Mercury will lie just under 8 arcminutes northeast of the center of the solar disk.

At approximately 6:29 UT Mercury reaches contact III, the last moment that the planet's entire disk is visible. The transit concludes about two minutes later at contact IV. All times listed above are geocentric times (for the center of the Earth); actual times may vary by a minute or so depending on the observer's location.

Luckily, unlike solar eclipses, large areas of the Earth can witness a transit. The width of Mercury's shadow cone (the region where a transit is visible) at Earth's distance is large because of the planet's great distance. Compared to Earth's diameter of only 12,800 kilometers, the 2 million-kilometer-wide shadow cone of Mercury virtually guarantees that when conditions for a transit are satisfied observers on the entire day side of Earth can see it. On November 13 this corresponds to most of the Eastern Hemisphere.

The map above shows where the transit will be visible. The entire transit can be seen from Australia, New Zealand, India, Indonesia, Southeast Asia, China, and Japan. For people living in most of Africa, the Middle East, eastern Europe, and western Siberia, the transit starts before sunrise, so the beginning will not be visible, but the rest of the event will be. People in eastern Siberia, southwestern Alaska, Hawaii, and all except the extreme eastern parts of the Pacific Ocean will be able to see the start of the transit, but the Sun will set before it is completed.

For many observers just watching the transit of Mercury can be satisfying enough. However, if you are not content to simply watch the tiny planet drift above the solar photosphere, you can also time the transit. Precise measurements of the times of the four contacts have been used to increase the accuracy of our positions for Mercury, as well as determine its diameter. If this interests you, send your observations, along with the exact coordinates of your geographic location, to the Almanac Office, U.S. Naval Observatory, Washington, D.C. 20390.

In either case, you will need to use some sort of optical aid for seeing Mercury. Because its angular diameter is slightly less than 10 arcseconds, a telescope with at least a 2-inch (50mm) aperture will be necessary to see Mercury's disk.

But therein lies a great danger. If you aren't absolutely sure that the solar filter you're using on your telescope can adequately protect your eyesight, don't try to view the transit! It would be much better to miss a once-in-a-decade view of the transit than to have it be your last view of anything.

There are two satisfactory ways to observe the transit through a telescope. The first is by using a full-aperture solar filter over the front end of your scope. This reduces the Sun's intensity to about 1/100,000 of its normal brightness, allowing for safe and easy viewing as long as the filter is securely attached.

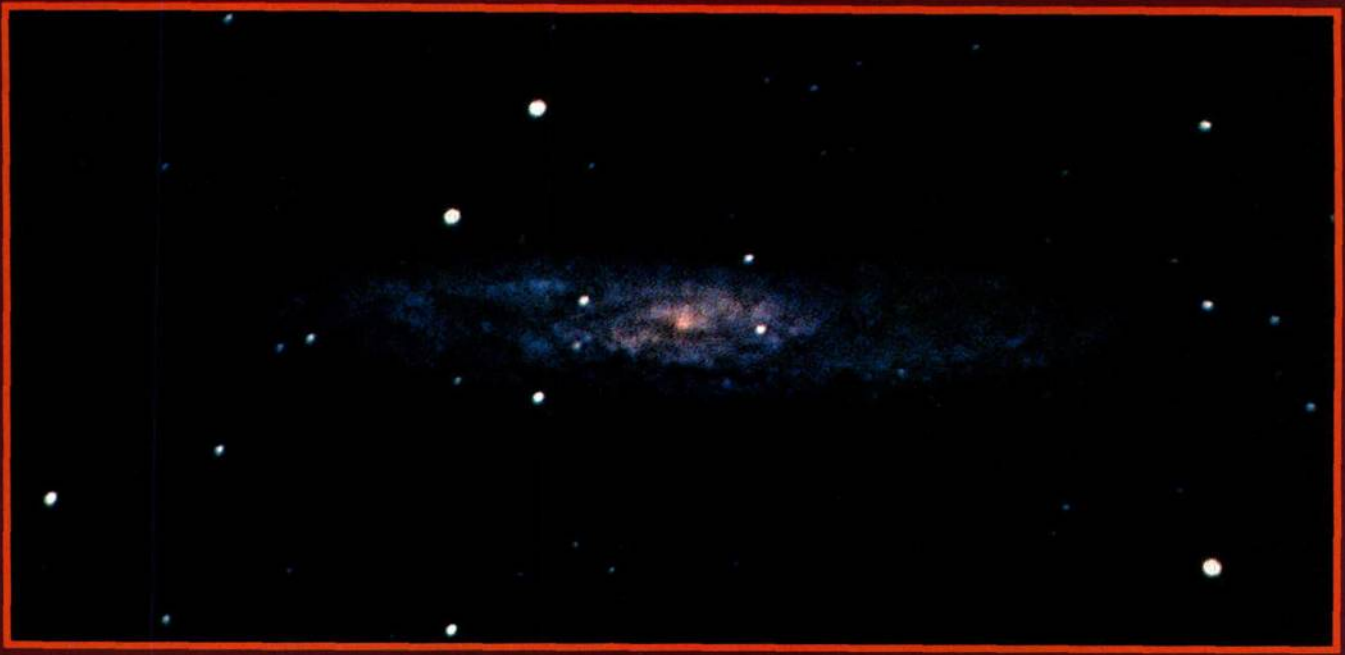
The second method is known as solar projection and can be used safely with almost any telescope. With this method you project the image of the Sun formed by the telescope onto a white screen located a couple of feet from the eyepiece. When using this technique stop down the aperture by 3 or 4 inches to compensate for the brightness of the Sun.

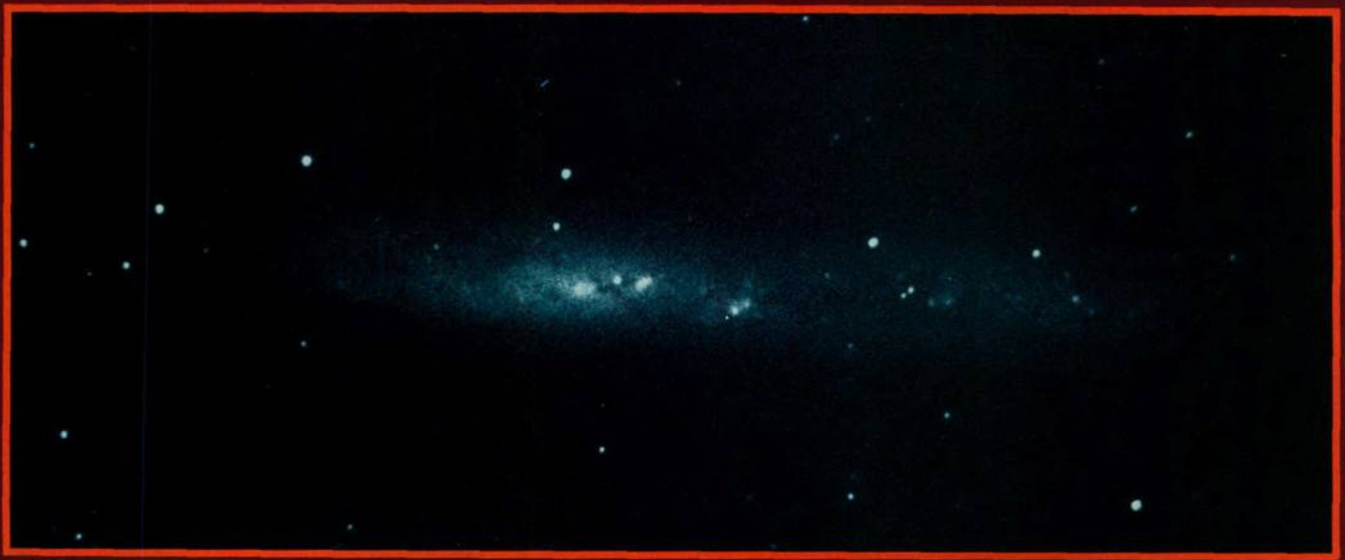
Also avoid letting anyone get in the light path after it exits the telescope as the heat can cause severe burns. Periodically rest your telescope by pointing it away from the Sun to avoid heat buildup. Use only low magnification eyepieces and avoid using your best eyepieces; these often contain multiple lenses cemented together that can be severely damaged by the concentrated heat from the Sun.

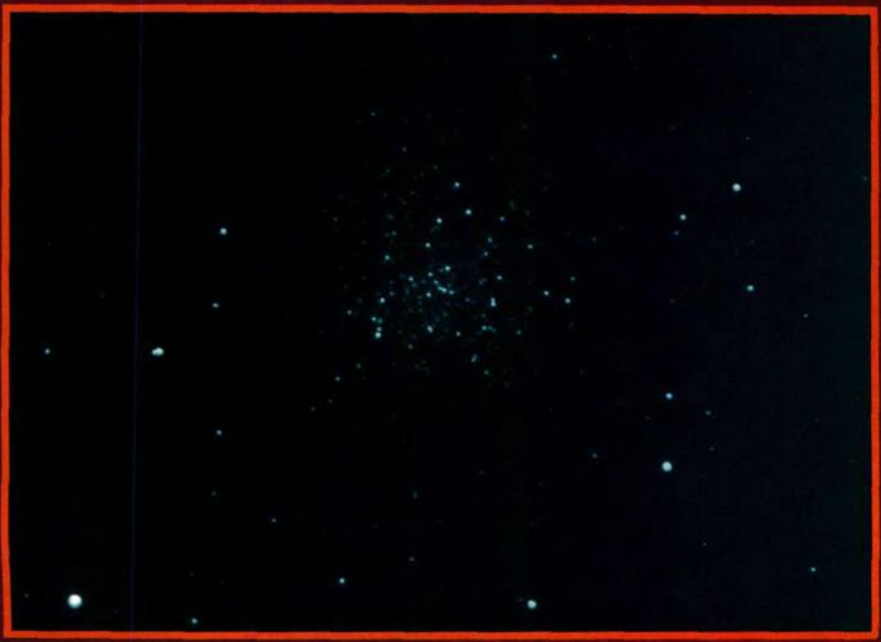
It has been thirteen years since we last saw a transit of Mercury. There has been a lot of progress in amateur astronomy since that time, from the wide availability of quality telescopes to great advances in astrophotography. Professional astronomers have seen no less of a boom, with new equipment leading to new discoveries and major theoretical breakthroughs in many areas.

But there is still something timeless about the celestial movements of the planets. After parting this November, Mercury and the Sun will not meet again until November 6, 1993. But as luck would have it, that event will also only be visible from the Eastern Hemisphere. Not until November 15, 1999, will long-suffering Western Hemisphere observers again witness a transit.

— Richard Talcott







Top: NGC-253 is one of the brightest, largest, and most detailed galaxies in the sky. It appears as a large silvery needle of light in small scopes. Photo by Jack B. Marling.

Above: NGC-55 is an edge-on barred spiral galaxy that is as long as the Moon is wide. Easily visible in small scopes, it shows mottled patches of light and dark. Photo by Martin C. Germano.

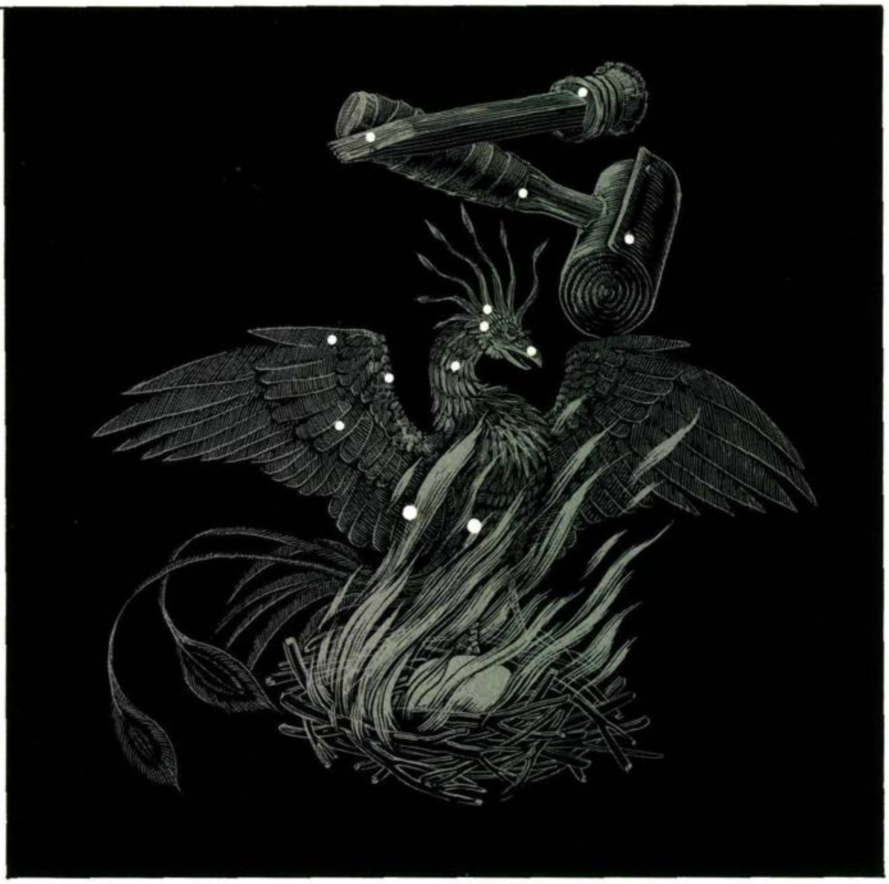
Left: NGC-288 is a bright globular cluster visible in small scopes as a speckled haze some 10′ across. High power with large backyard scopes completely resolves this fine group of suns. Photo by Martin C. Germano.

Sculptor

Scl
Sculptoris

Phoenix

Phe
Phoenicis



Keith Ward

Between the bright stars Fomalhaut in Piscis Austrinus and Achernar in Eridanus are the faint constellations **Sculptor** and **Phoenix**. Sculptor represents a sculptor's tools and Phoenix is the mythical bird that rises from the ashes of a funeral pyre. Since they lie away from the plane of the Galaxy in a sparse region of stars, both are unimpressive to the naked eye. Sculptor's brightest star is only a magnitude-4.4 object. Phoenix's brightest star is an orange-colored sun shining at magnitude 2.4, but the remaining naked-eye stars in that group are 3rd- and 4th-magnitude objects

Hidden in the apparently empty region, however, are a number of galaxies that show detail when viewed with medium and large backyard telescopes. Among them are NGC-253, the fourth best galaxy for small telescopes; NGC-55, an edge-on barred spiral; and the Sculptor system, a dwarf elliptical that is a member of the Local Group of galaxies.

Lying 7.5° south of Beta (β) Ceti and 3.5° northeast of the South Galactic Pole, **NGC-253** is easy to find by star-hopping across several 6th- and 7th-magnitude stars and the fuzzy, 8th-magnitude globular cluster, NGC-288. Shining at magnitude 7.1 and spanning 25.1′ by 7.4′ (the galaxy's long axis nearly covers the width of the Moon), NGC-253 is bettered only by the Magellanic clouds and M-31 as the best galaxy for small telescopes.

Although NGC-253 is large, it shines so brightly that its surface brightness is high. This affords backyard viewers with even 3- or 4-inch telescopes a good view of an object that obviously looks like a galaxy, despite the fact that its declination is −25° and it never rises more than a few degrees above the treetops for many Northern Hemisphere viewers.

To get the best view of NGC-253, employ a low-power eyepiece. First inspect the overall shape of this galaxy and use averted vision to see obvious details within the core and spiral arms. Then switch to moderately high power (about 15x per inch of telescopic aperture) and look for mottled patches (dust in the spiral arms), the tiny, stellar nucleus, and subtle spiral structure.

NGC-253 is the brightest member of a group of galaxies called the Sculptor group, which includes NGC-55, NGC-300, and NGC-7793. These galaxies lie approximately 3.5 megaparsecs away and, together with NGC-45 and NGC-247 in Cetus, comprise one of the closest galaxy groups outside our own Local Group.

Some 2° southeast of NGC-253 lies the impressive globular **NGC-288**. This object covers 13.8′ of sky and shines at magnitude 8.1, making it readily visible in finder scopes as a hazy patch of light. Small scopes show a large disk of gray light peppered by occasional resolved stars across its face.

NGC-288 is very popular with observers since it is a "loose" cluster and resolves nicely into myriad stars when viewed at high power with 6- to 12-inch telescopes. At moderate powers the cluster takes on a speckled appearance as its brightest stars "pop" out of the background glow. Does your telescope show you a mottled, partially resolved NGC-288?

In south-central Sculptor, about 8.5° south-southeast of NGC-253, lies one of the oddest members of our Local Group of galaxies. The dwarf elliptical known as the **Sculptor system** is an extreme example of its class; it is only about 50 times larger than a globular cluster and it contains a very low density of stars.

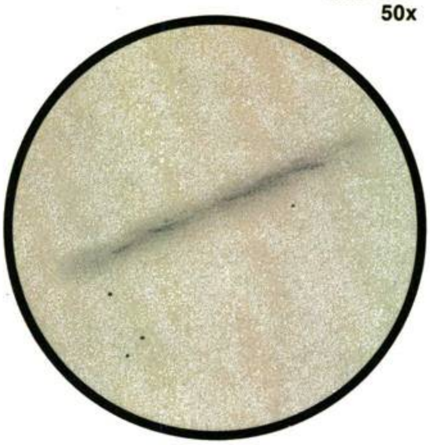
Only 90 kiloparsecs distant — therefore close as galaxies go — the Sculptor system is notoriously difficult to view with any telescope. Its brightest stars glow dimly at magnitude 18, and despite the fact that it has a total magnitude of 10.5, that light is spread out over a large area. It may be visible on very dark, clear nights as a faint haze roughly 1° in diameter in the largest backyard telescopes.

In northeastern Sculptor, near Tau (τ) Sculptoris, lies **NGC-613**, a bright barred spiral. Measuring 5.8′ by 4.6′, 10th-magnitude NGC-613 is easily visible as a nebulous, slightly oval patch of light in a 3-inch telescope. In a 6-inch scope at high power the galaxy appears as a bright, condensed core surrounded by a fainter, unevenly lit halo of nebulosity some 4′ across. Larger scopes show mottling in the nebulous halo, suggesting NGC-613's barred spiral arms.

Near the star Eta (η) Sculptoris is a barred spiral designated **NGC-134**. Compare this object carefully with NGC-613. They have the same revised Hubble classification, shine at virtually the same brightness, and measure about the same angular size (NGC-134 is a little larger). Which do you find *you* favor?

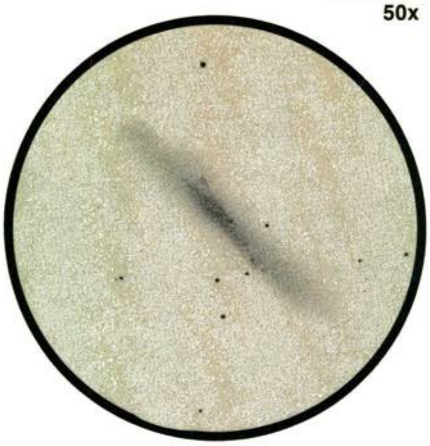
For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

NGC-55



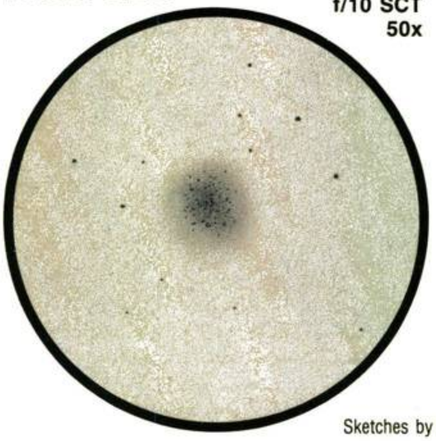
8-inch
f/10 SCT
50x

NGC-253



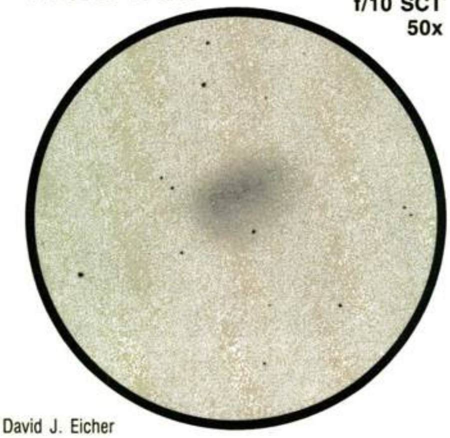
8-inch
f/10 SCT
50x

NGC-228



8-inch
f/10 SCT
50x

NGC-300



8-inch
f/10 SCT
50x

Sketches by David J. Eicher

South and a little west of the Sculptor system, near the border with Phoenix, is a large galaxy with a low surface brightness called **NGC-300**. This object spans some 20.0′ by 14.8′ and shines with a total magnitude of 8.7 in blue light and roughly one magnitude brighter in the yellow-green part of the spectrum that the eye is most sensitive to. Known for its relatively bright and recognizable core, NGC-300's spiral arms are extremely faint. Under ordinary conditions they may require a 10- or 12-inch telescope to make out as a faint haze.

The largest galaxy in Sculptor is **NGC-55**, a huge barred spiral oriented edge-on to our line of sight. To find NGC-55, look about 3.5° north-northwest of Alpha (α) Phoenicis. The galaxy spans 32.4′ by 6.5′ across and shines at magnitude 8.2 in blue light, making it visible with any optical aid as a long, thin sliver of silvery light.

A 6-inch telescope reveals that NGC-55 is mottled by dust lanes and that the nucleus is encapsulated within a small, bright oval core. Larger scopes show progressively more detail in the arms and around the nucleus, and nearly 30′ worth of galaxy — a distance equivalent to the width of the Moon!

Five more impressive galaxies lie in Sculptor. **NGC-24** is a magnitude-11.5 Sb-type spiral measuring 5.5′ by 1.6′ across. It lies near the northern border with Cetus and is visible in large finder scopes as a misty patch of weak light. **IC 5332**, an Sd-type spiral, lies in the southwestern part of the constellation near a 7th-magnitude double star. This galaxy appears like a small, unresolved globular cluster since it shines at 10th magnitude and spans 6.6′ by 5.1′.

One degree east of the bright star Beta (β) Sculptoris is the barred spiral **NGC-7713**, a blue magnitude 11.6 object some 4.3′ by 2.0′ across. **NGC-7755**, another barred spiral, lies in the center of a triangle formed by Mu (μ), Zeta (ζ), and Delta (δ) Sculptoris. It glows at blue magnitude 11.8 and covers 3.7′ by 3.0′. Nearby is **NGC-7793**, a large, close Sd-type spiral glowing at 9th magnitude.

Phoenix contains two bright objects for small telescopes. **NGC-625** is a bright little barred spiral lying 2° northeast of Gamma (γ) Phoenicis. Small scopes show it as a condensed, bright nuclear region 30″ across surrounded by a 3.0′ by 1.3′ diameter haze of greenish light. Its overall magnitude is 12.3 in blue light, making its V magnitude close to 11.

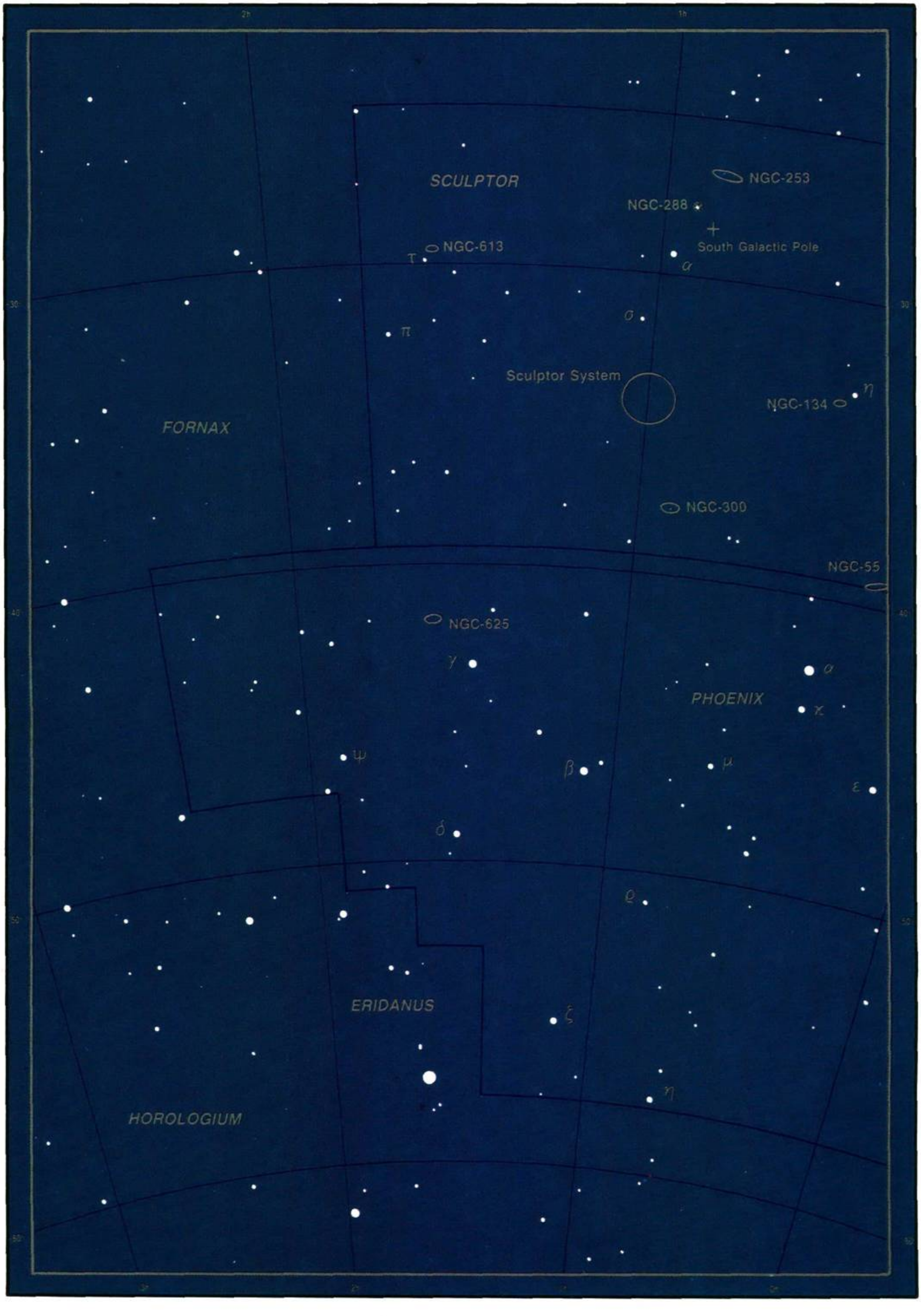
The unusual Cepheid variable star **SX Phoenicis**, some 8° west of Alpha Phe, can be interesting to observe with a small telescope. Its magnitude range is 6.8 to 7.5, so that you must carefully compare its brightness with surrounding stars to accurately determine the star's brightness. The period for SX Phe is 0.05 days, or just 1.2 hours, so you can see it change noticeably during a single observing session.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
NGC-24		§	0h 09.9m	−24°58′	11.5	5.5′x 1.6′	Sb
NGC-55		§B	0h 14.9m	−39°11′	8.2	32.4′x6.5′	SBm:
NGC-134		§B	0h 30.4m	−33°15′	10.1	8.1′x 2.6′	S(B)b+
NGC-253		§	0h 47.6m	−25°17′	7.1	25.1′x 7.4′	Sc pec
NGC-288		•	0h 52.8m	−26°35′	8.1	13.8′	
NGC-300		§	0h 54.9m	−37°41′	8.7_B	20.0′x 14.8′	Sd
Sculptor System		0	0h 59.8m	−33°42′	10.5_B	—	dE3
NGC-613		§B	1h 34.3m	−29°25′	10.0	5.8′x 4.6′	S(B)b+
NGC-625		§B	1h 35.1m	−41°35′	12.3_B	3.0′x 1.3′	SBm:
IC 5332		§	23h 34.5m	−36°06′	10.6	6.6′x 5.1′	Sd
NGC-7713		§B	23h 36.5m	−37°56′	11.6_B	4.3′x 2.0′	SBd
SX Phe		CV	23h 46.5m	−41°35′	6.8↔7.5	0.05d	
NGC-7755		§B	23h 47.9m	−30°31′	11.8_B	3.7′x 3.0′	S(B)b
NGC-7793		§	23h 57.8m	−32°35′	9.1	9.1′x 6.6′	Sdm

CV	*Cepheid Variable*
•	*Globular Cluster*
§	*Spiral Galaxy*
§B	*Barred Spiral Galaxy*
0	*Elliptical Galaxy*

H = Hubble type for galaxies

Subscript "P" denotes photographic magnitude; subscript "B" denotes blue magnitude.


2h
1h
SCULPTOR
NGC-253
NGC-288
South Galactic Pole
NGC-613
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Sculptor System
NGC-134
η
FORNAX
NGC-300
NGC-55
-30
-40
NGC-625
γ
α
PHOENIX
χ
ψ
β
μ
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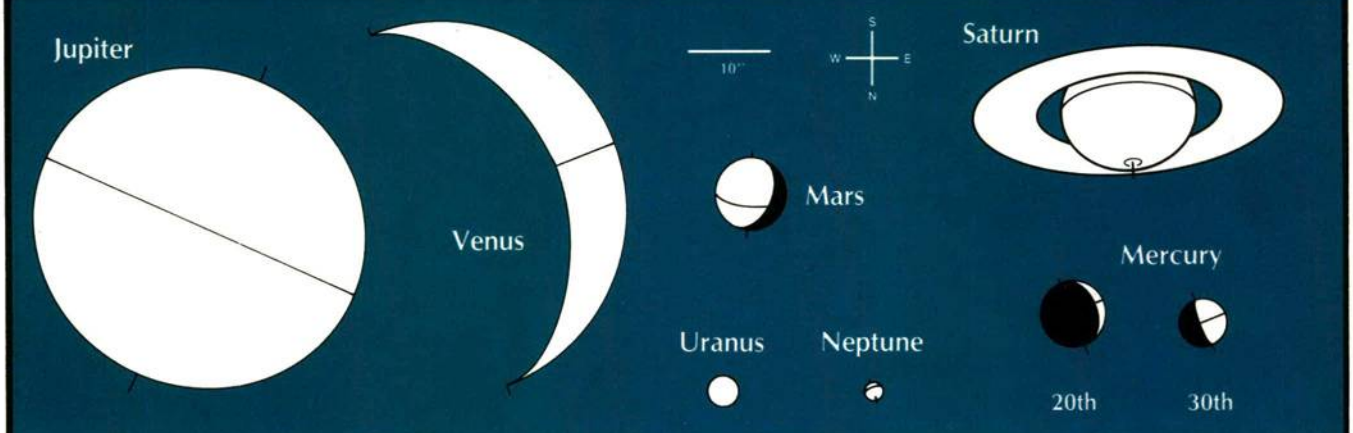
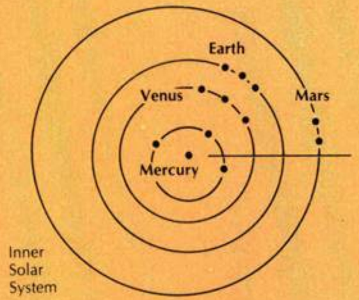
δ
ρ
-50
ERIDANUS
ξ
η
HOROLOGIUM
-60
3h
2h
1h
0h

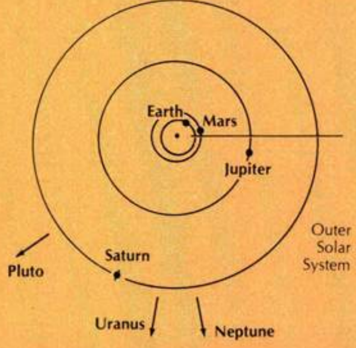
Planetary Data November 1986


Jupiter
Venus
10″
S
W
E
N
Saturn
Mars
Mercury
Uranus
Neptune
20th
30th

				Angular	%	Distance (AU) from:		Longitude:			
		Date	Mag.	Size	Illum.	Earth	Sun	Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.3′	—	0.992	—	—	218°16.4′	14h 24.3m	−14°19.4′
		15	−26.8	32.4′	—	0.989	—	—	232°19.7′	15h 20.4m	−18°24.0′
		30	−26.8	32.5′	—	0.986	—	—	247°28.8′	16h 23.5m	−21°35.4′
Mercury	☿	1	0.4	8.2″	35%	0.817	0.372	346°42.3′	239°14.4′	15h 45.5m	−22°43.3′
		15	4.3	9.8″	2%	0.686	0.309	61°58.7′	228°22.8′	15h 04.2m	−16°33.9′
		30	−0.5	6.7″	61%	1.003	0.349	150°06.8′	227°46.7′	15h 03.3m	−14°47.6′
Venus	♀	1	−4.2	60.9″	1%	0.273	0.724	35°37.5′	225°50.7′	14h 44.8m	−22°07.3′
		15	−4.3	59.4″	3%	0.281	0.722	58°03.9′	217°43.0′	14h 17.2m	−16°40.2′
		30	−4.6	48.7″	16%	0.343	0.720	82°12.8′	215°49.4′	14h 13.3m	−12°39.3′
Mars	♂	10	−0.2	9.9″	85%	0.949	1.396	4°29.7′	319°32.0′	21h 30.2m	−16°47.9′
		20	−0.1	9.2″	86%	1.021	1.403	10°40.9′	326°06.6′	21h 55.6m	−14°19.3′
Jupiter	♃	15	−2.6	43.4″	99%	4.532	4.969	353°46.8′	343°14.7′	23h 00.3m	−7°51.0′
Saturn	♄	15	0.5	15.1″	100%	10.949	10.011	251°37.0′	250°05.5′	16h 34.7m	−20°27.7′
Uranus	⛢	15	5.7	3.5″	100%	20.039	19.175	262°13.4′	261°04.0′	17h 20.7m	−23°14.6′
Neptune	♆	15	8.0	2.2″	100%	30.972	30.241	275°16.5′	274°16.3′	18h 18.2m	−22°21.1′
Pluto	♇	15	13.8	0.1″	100%	30.623	29.704	217°24.5′	218°04.5′	14h 43.2m	0°53.1′


Earth
Venus
Mars
Mercury

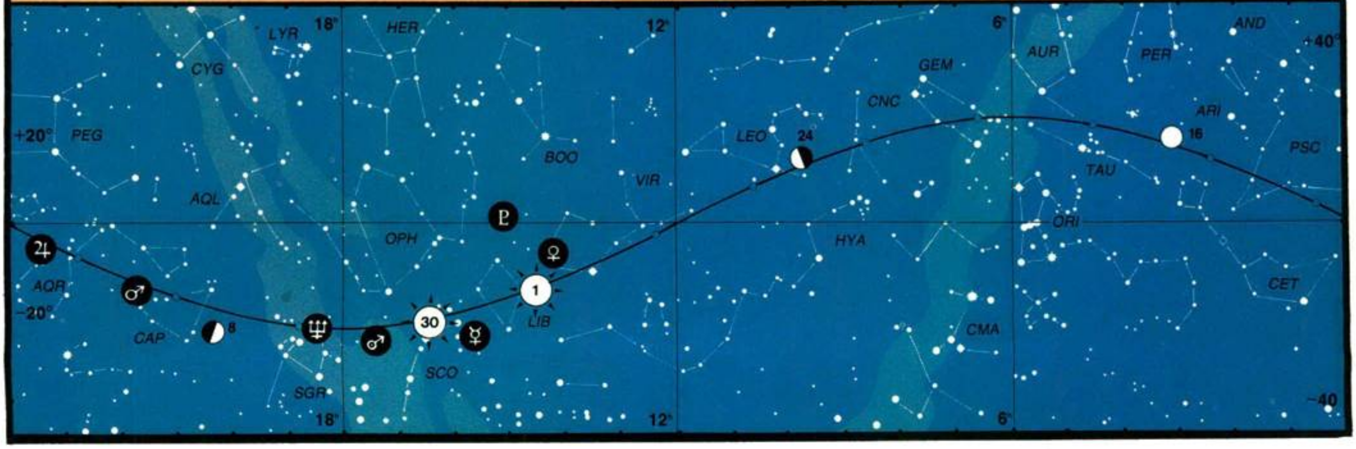
Inner Solar System


Earth
Mars
Jupiter
Pluto
Saturn
Uranus
Neptune

Outer Solar System

Moon Data

New Moon	November 2 at 6h02m
First Quarter	November 8 at 21h11m
Full Moon	November 16 at 12h12m
Last Quarter	November 24 at 16h50m
New Moon	December 1 at 16h43m
First Quarter	December 8 at 8h01m
Perigee: Nov. 4 at 2h30m	361,816 km
Apogee: Nov. 19 at 22h14m	406,029 km


LYR
18h
HER
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AND
+40°
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PER
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24
16
PSC
BOO
TAU
VIR
AQL
♇
ORI
OPH
HYA
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♀
AQR
1
CET
♂
−20°
30
8
♆
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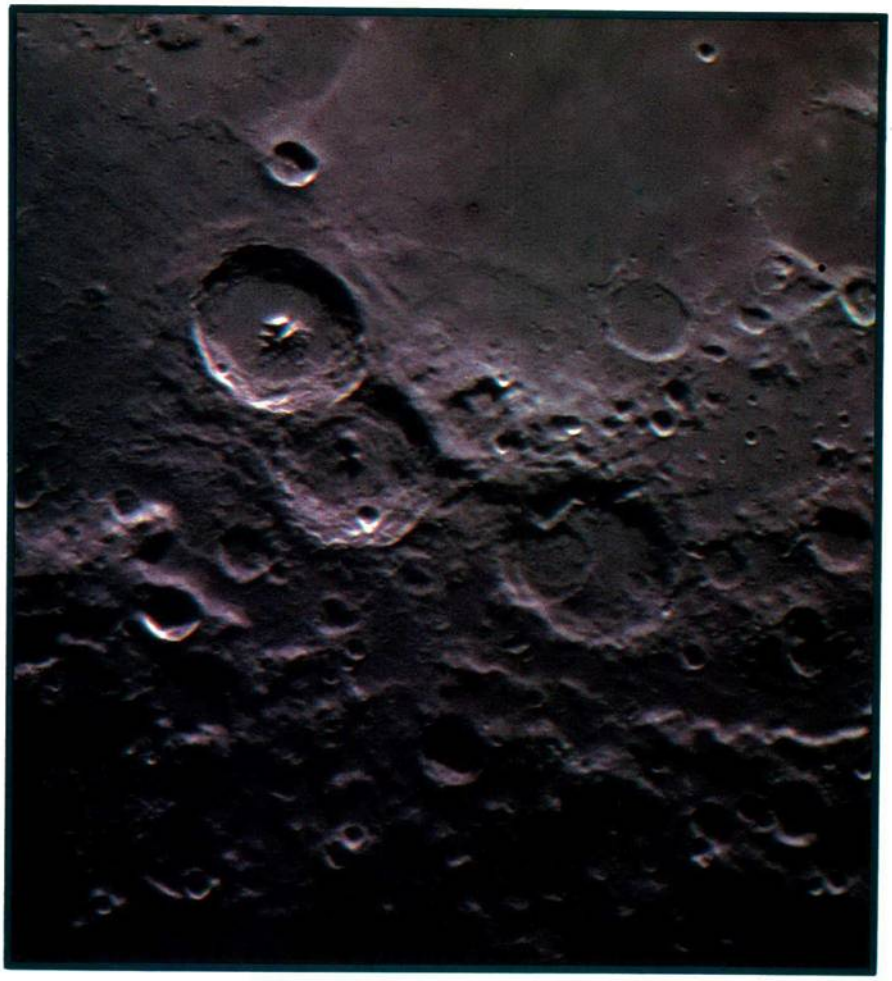


Lunar craters Catherina, Cyrillus, and Theophilus show with crystal clarity in this photo made with the 1-meter f/16 telescope and Kodachrome 64 film at Pic du Midi Observatory in France. Photo by Serge Brunier.

Mercury

When it passes through inferior conjunction on November 13, Mercury will transit the face of the Sun — the first such event since 1973. Unfortunately, nearly all of Earth's Western Hemisphere will be experiencing night when the transit takes place. The most favored terrestrial region is eastern Asia, Japan, China, India, southeast Asia, the Indonesian archipelago, Australia, and New Zealand.

At least the start of the transit is visible before sunset for observers in Hawaii and southwestern Alaska and the Aleutian Islands. These luckily-placed viewers should use safe solar observing techniques (an over-the-aperture filter or eyepiece projection) with about 100x magnification. Mercury's 9.9'' disk — a small, black dot — will crawl onto the Sun at a position angle of 85°, almost due east on the solar disk. For Hawaiian viewers the event commences at around 1h40m UT and ends at sunset with the five-hour transit only partly complete. (The next transit of Mercury occurs November 6, 1993, but it, too, is invisible from North America. Not until November 15, 1999, will a transit be seen here.) See Gazer's Gazette on page 107 for more information.

After transiting the Sun, Mercury will move swiftly into the morning sky, becoming prominent during the hour before sunrise. By the 20th, look for it low in the southeast. Mercury reaches greatest western elongation (and elevation) on the 30th when it will be 10° high, 45 minutes before sunrise. Thereafter it will remain visible until December 22 or 23. Weather permitting, this is your best chance this year to get a look at the elusive planet with your telescope.

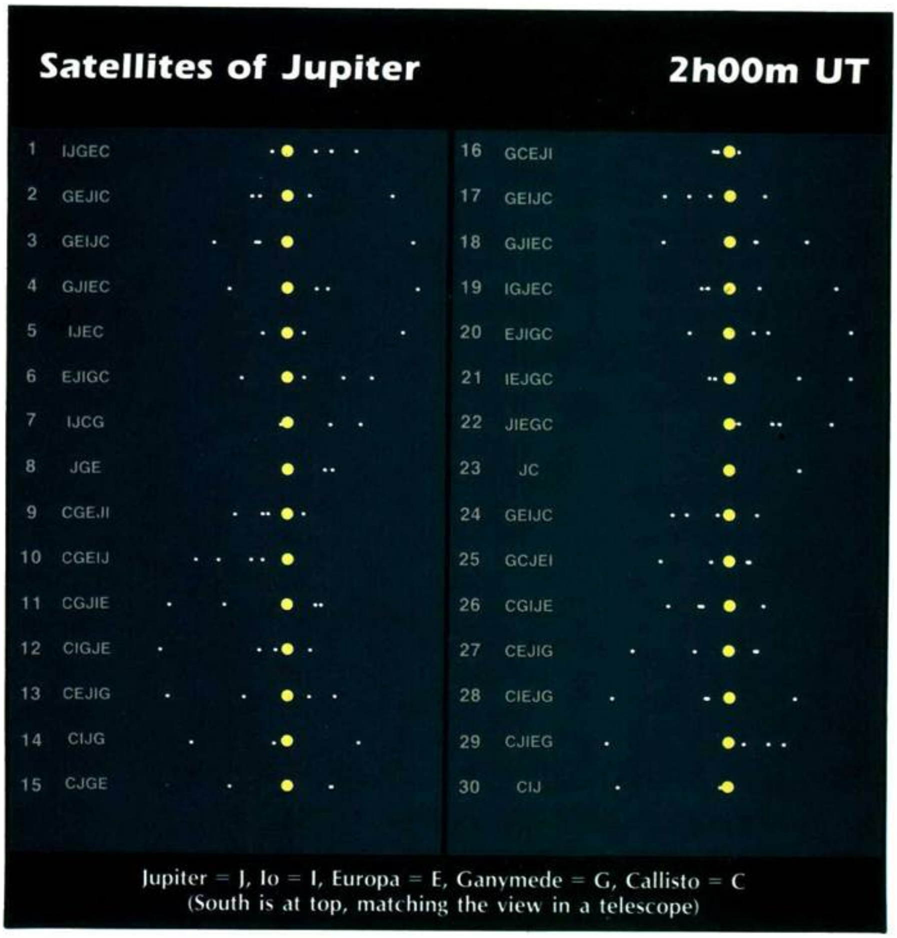
Venus

Also passing through inferior conjunction this month (November 5), Venus will, like Mercury, become a morning object. (It will not transit the Sun, however. That doesn't occur until June 8, 2004!) First becoming visible at about magnitude −4.3 at mid-month, Venus will be 20° high by month's end.

This is a good time to observe Venus with a telescope since it has a large apparent size and its phase is noticeably changing almost daily. Because the disk is glaringly bright, it's a good idea to keep viewing well into twilight so that the contrast between planet and sky in your eyepiece is low and the crescent disk is clearly visible.

Mars

Slightly gibbous because we are glimpsing part of its nighttime hemisphere, Mars presents relatively little of interest this month, even at high magnification.



Satellites of Jupiter **2h00m UT**

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)

Left: During Mars' closest approach on the night of July 17, 1986, both the southern polar cap and wedge-shaped Syrtis Major were visible. Photo by Albert Tan Boon Wah, using an 8-inch f/10 SCT, eyepiece projection with a 7mm ocular, and a 2-second exposure on Ektachrome P 800/1600, pushed to ISO 800.
Right: Fellow Frenchman Patrick Martinez' shot of Halley's Comet on April 13, 1986, is this month's $100 "Best Astrophoto" winner. Martinez used a 300mm lens, Fujichrome 400 film, and a 40-minute exposure.

On the 18th, Mars lies just over 1 astronomical unit (149 million kilometers) away and its amber-orange disk is only 9.3″ across. During moments of good seeing use high power to look for changes in the size of the southern polar cap. From one week to the next careful observations ought to show differences in its size.

With low magnification eyepieces it will be fun to watch Mars as it passes near three stars in Capricornus. Around the 5th and 6th Mars will begin to overtake 4.3-magnitude Iota (ι) Cap, then it passes 3.7-magnitude Gamma (γ) and the 2.9-magnitude double star Delta (δ) on the 14th and 17th, respectively.

Minor Planets

1 Ceres is in conjunction with the Sun on the 2nd and is out of sight all month long.

2 Pallas (magnitude 9.3) is moving southeast in central Virgo. On the 10th at 0h25m UT it passes 31′ north of 3.4-magnitude Zeta (ζ) Virginis. Pallas' positions:

1st: 13h 18m 25s, +0° 21.6′
10th: 13h 34m 40s, −0° 04.3′
20th: 13h 52m 29s, −0° 25.3′
30th: 14h 09m 59s, −0° 36.8′

Pallas rises around 4:30 a.m. local time on the 15th.

3 Juno (11.3) lies in Serpens Cauda. Its positions:

1st: 17h 19m 41s, −12° 34.6′
10th: 17h 31m 35s, −13° 02.0′
20th: 17h 45m 24s, −13° 26.1′
30th: 17h 59m 45s, −13° 43.2′

Juno sets about 7:30 p.m. local time at mid-month.

4 Vesta (7.1) is in Cetus near the border with Pisces. Its positions:

1st: 0h 31m 59s, −8° 37.1′
10th: 0h 27m 56s, −8° 27.4′
20th: 0h 26m 01s, −7° 56.8′
30th: 0h 26m 46s, −7° 08.4′

Vesta sets around 3 a.m. local time on the 15th.

9 Metis (9.6) is moving retrograde in Taurus, north of the Hyades. It is at opposition on November 28. Its positions:

1st: 4h 42m 33s, 20° 09.6′
10th: 4h 36m 35s, 20° 25.0′
20th: 4h 27m 21s, 20° 39.9′
30th: 4h 16m 38s, 20° 52.4′

Metis is visible all night long.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star map (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

In the evening hours Jupiter is excellently placed for telescopic observations and for public star gazing. On a clear night around the 9th, when Mars and the Moon lie near Jupiter, invite some non-astronomical friends over. Take them outside and show them this small part of the sky with your telescope.

After "wowing" them with the Moon (and probably disappointing them with Mars), use low magnification on Jupiter and point out its two dark equatorial belts and the Red Spot, if it's visible. Then shift to higher magnification, adding perhaps a pale red or blue filter, and explore the disk in more detail. Who knows? You may make some converts to backyard astronomy.

Saturn

Saturn is too close to solar conjunction (December 4) to be visible this month.

Uranus

Your telescope might be able to show Uranus (poorly, and at low elevation) at the beginning of November, but the planet will vanish into the evening twilight sometime during the second half of the month. Forty-five minutes after sundown on the 1st, Uranus will be 13° high and due southwest. Look for an object at 6th magnitude that sports a pale greenish disk 3.5″ in diameter.

Neptune

Neptune won't be much easier to spot than Uranus. On the 1st it lies in azimuth 212° at an elevation of 21°, 45 minutes after sunset. (This is a little over 1° southeast of 3rd-magnitude Mu (μ) Sagittarii.) By the end of the month, the altitude is only 10° (azimuth 230°). Neptune has a 2.2″ grayish disk that is 8th magnitude in brightness.

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